THE

ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY
AND ASTRONOMICAL PHYSICS

VOLUME II AUGUST 1895 NUMBER 2

A NEW FORM OF STELLAR PHOTOMETER.

By EDWARD C. PICKERING.

In 1877 observations were undertaken at the Harvard College Observatory of the relative light of the components of double stars. The photometer chiefly employed is described in the *Annals* **11**, 1, Fig. 1, and is still in use. It consists of a double image prism which can be moved along the axis of the telescope to any desired distance from the focus and a Nicol prism in front of the eyepiece which can be turned by an amount which is measured with a graduated circle and index. This instrument leaves little to be desired in the measurement of close double stars. Nearly all sources of systematic error may be eliminated when it is properly used, and the relative brightness of two adjacent stars may be determined with great accuracy. Besides the measures given in Volume XI, this photometer has been used for many years in measuring the brightness of the satellites of Jupiter when undergoing eclipse and also for measuring variable stars and doubles. Examples of the accuracy attainable with it will be found in the *A. N.*, **134**, 348 and **135**, 127, from which it appears that the results on different nights will give average deviations considerably less than a tenth of a magnitude. This instrument gave rise also to the meridian

photometer, which differs from it in principle only by bringing together the images of stars formed by two object-glasses instead of two images formed by the same object-glass, so that stars however distant can be compared. The same degree of accuracy is not, however, attainable with the meridian photometer, since owing to varying density of the air, haze, and other causes, the images of the stars compared will not resemble each other as closely when they are distant as when they are adjacent. A modification of the first of these photometers attached to the fifteen-inch equatorial enables two stars as much as 5′ apart to be compared. But this seems to be about the limit attainable with a telescope of this size. With a smaller telescope more distant stars may be compared, but of course only comparatively bright stars can then be measured. Three difficulties arise when the distance between the stars is large. First, the double-image prism must be large or a portion of the object-glass will be cut off and light thus lost when the prism is moved far from the focus. Secondly, the images will be colored and will in fact become short spectra, since the double-image prisms are not achromatic. The lengths of these spectra are nearly proportional to the apparent angular distance apart of the objects compared. When the stars differ in color, as frequently happens with double stars, the difference in the spectra introduces a new form of error. Thirdly, if double-image prisms having a large angle of separation are used to compare distant stars, the emergent pencils formed by the two images of the object-glass will only partly overlap and thus introduce a new source of error. A portion of one of the pencils may be cut off by the edge of the pupil of the eye, or the unequal transparency of different portions of the cornea may unduly diminish the light of one star.

All of these difficulties are avoided by the form of photometer represented in Plate VI. The double-image prism is placed at the focus, as in the meridian photometer, and the two images of the object-glass are formed by two achromatic prisms which can be slid by a chain and sprocket wheel to any desired distance from

the focus. A screw is cut on the axis of the sprocket wheel, and turns a wheel which is divided so as to indicate the position of the prisms and accordingly the distance apart of the stars. A Nicol prism and eyepiece are placed behind the double-image prism, and the position of the Nicol prism is read by a graduated circle and index. A Foucault prism is in practice found preferable to a Nicol, since although the loss of light is slightly greater, the field is less restricted.

The angle of separation of the images formed by the double-image prism is nearly equal to the sum of the deviations of the achromatic prisms. The emergent pencil of the ordinary image of one, therefore, nearly coincides with the emergent pencil of the extraordinary image of the other, as in the case of the meridian photometer. As in that instrument the two remaining pencils are cut off by the eyestop. In fact the theory of this photometer is the same as that of the meridian photometer, the two images of the object-glass taking the place of the two object-glasses of the latter instrument. Both instruments have the same advantages as regards the possibility of eliminating nearly all forms of systematic error. The images of two stars may be brought together by moving the achromatic prisms towards or from the focal plane of the telescope and by rotating the whole photometer. Each set of measures consists of settings in the four positions of the Nicol prism in which the images of the two stars appear equal. The images are always brought near together and reversed between the second and third settings. After every eight settings the entire instrument is rotated 180°, since it is found that certain sources of systematic error are thus eliminated. Several sets of measures, generally four or six, are made of each object observed. This is found advantageous, since several minutes are always expended when setting a large telescope on a new object, in turning the dome, moving the chair, reading the circles, identifying the objects, and adjusting the photometer. When this is done it saves time to repeat the measures and thus reduce the accidental errors as much as possible. With the meridian photometer all these adjustments

are made in a few seconds. It is therefore better with this instrument to take each evening only one, or at most two sets and repeat the measures on several evenings. But likewise, with the new photometer, each object is regularly observed on as many as three dates.

One-half of the light of each star is lost in the process of polarization. The losses by reflection and absorption of the various prisms used reduce the brightness of the stars by at least one magnitude. This is equivalent to a reduction of the aperture of the telescope by about one-third when the photometer is used. The faintest stars that can be measured with the fifteen-inch telescope are of about the 13.5 magnitude. When the greatest accuracy is desired the difference in brightness of the stars compared should not exceed five or six magnitudes, although it is possible to measure as large intervals as eight or nine magnitudes. In the photometer represented in Plate VI, the images are separated 4° by the double-image prism. The achromatic prisms are about six centimeters on a side and the deviation of the light which they occasion is about 2° 15′. They may be moved about 90 centimeters along the axis of the telescope. Their combined deviation is somewhat greater than that of the double-image prism when they are brought near it, but it is less when they are moved to the other end of the photometer. The two emergent pencils exactly coincide only for a certain position of the prisms, but they never separate by an amount likely to cause error. When the prisms are at their greatest distance from the focal plane the images of two stars 35′ apart may be brought together. This distance becomes 3′ when the prisms are moved near the double-image prism. In either extreme position the field is somewhat limited, since a portion of the emergent pencil may be cut off if the image is not in the center of the field. This is best tested by covering the center of the object-glass and throwing the stars out of focus. Their images will then appear as circular rings of light which will be broken, that is, will become incomplete circles, if any portions of the cones of light are cut off.

Since stars as distant as 35′ may be compared, at least one star as bright as the eighth or ninth magnitude would probably always be available for comparison. The brightness of this star can afterwards be determined with the meridian photometer and the scale of that instrument thus extended to any star brighter than the fourteenth magnitude. In this photometer the two stars are compared directly; the accidental errors should therefore be less than in the Zöllner photometer and similar instruments, in which each star in turn is compared with another source of light.

This photometer is now attached to the fifteen-inch equatorial of this Observatory. It is regularly used on almost every clear night by Mr. O. C. Wendell, who made the observations described below in three tests which have been made of the instrument.

As the first of these tests, three stars were selected, *B.D.*+79° 169,+79° 171 and a star of the eleventh magnitude preceding *B.D.*+79° 169 by 29ˢ.9 and north 7′.8. The brightness of each of these stars was then compared with the other two. The difference in brightness of the first and third exceeds six magnitudes and is as great an interval as can be accurately measured. Four sets of four measures each were made on May 3, 6, 29 and June 10, 1895, with the results 6.24, 6.40, 6.38 and 6.48. The mean of all is 6.38, showing that one star is about 356 times as bright as the other. The individual sets show an average residual of ±0.081, and the results for the different nights, ±0.065. Each reading differed only about 3° from the point where the images entirely disappeared, and a portion of the error arises from the difficulty in measuring this small angle. The circle is divided to degrees and is estimated to tenths. An error of one-tenth corresponds to a change in the result of 0.07 of a magnitude. If such small angles were ordinarily to be measured it would be better to have the circle more finely divided and moved by a tangent screw. Their effect on the final result is, however, nearly inappreciable. When smaller differences in magnitude were to be measured the results were still more accordant. Measures on the same nights of the difference in magnitude of +79° 169 and +79° 171 gave the results 3.54, 3.46, 3.48 and 3.56. The mean

is here 3.51 and the average deviation of the individual sets is ±0.036, and of the nights ±0.040. The measures of the two fainter stars were 2.61, 2.58, 2.72 and 2.69; mean 2.65, average deviation of sets, ±0.033; of nights, ±0.055. It will be noticed that the sum of the two smaller intervals, 3.51+2.65=6.16, is slightly less than the larger interval, 6.38. This is probably due to the convergence of the rays in the cone from the object-glass, owing to which a very bright star cannot be made to entirely disappear. (See *H. C. O. Annals*, **23**, 135.) A correction, which would be insensible unless the intervals are large, might be applied if future observations confirm this source of error.

A second test of this instrument consisted in measuring the light of a variable recently found by Mrs. Fleming in the constellation Cancer. Its approximate position for 1900 is R. A. $9^h\ 40^m$; Dec. $+25°\ 39'$. It was compared on four nights with the star *B.D.*$+26°$ 1901, mag. 7.3, which precedes it about $2^m\ 0^s.8$, and is north of it $22'.7$. The measures on May 10, 11, 13 and 16, 1895, gave the magnitudes 5.04, 5.19, 5.18 and 5.31, the average deviations of the separate sets being ±0.033, ±0.043, ±0.025 and ±0.042 respectively. The variation is thus confirmed, notwithstanding its small amount during this interval. On June 12, 1895, the variable was too faint for measurement, but a comparison with a star about three-tenths of a magnitude brighter gave the interval 5.92, with an average deviation of the sets ±0.122. The variable must therefore have changed by more than a magnitude. The average deviation is larger than usual, probably owing to the extreme faintness of the star.

A third test consisted in a series of continuous observations of the variable star U Ophiuchi on the evening of June 8, 1895. This star is of the Algol type, one of its minima occurring on June 8 at $14^h.8$ G. M. T. This star was compared continuously for three hours and a half with the star *B.D.*$+1°3411$, which is about $36'$ distant. The total number of settings was 308. The Moon was nearly full and the sky was covered with thin cirrus clouds irregularly distributed, which prevented observations with other instruments. One of the advantages of this form of pho-

tometer, especially when the stars compared are adjacent, is that passing clouds ordinarily affect equally the brightness of both stars compared, so long as the observations are reduced to the photometric scale. This would not be the case with the scale of Argelander or other empirical scales. Even the correction for atmospheric absorption, which should always be applied if great accuracy is desired, varies with the magnitude if the photometric scale is not used. It is then difficult, if not impossible, to apply it.

The error due to passing clouds increases with the distance apart of the stars, and, perhaps, caused the large residual in the second group of observations described below. All of the observations are grouped in the following table. Each group was composed of four sets of four settings each, except the last group, which contained five sets. The Greenwich mean time is followed by the observed difference of magnitude of U Ophiuchi and *B.D.*+1°3411, the latter star being always the fainter. The third column gives the average deviation of the four sets of which each group is composed. The fourth column gives the assumed true difference in brightness found graphically, and the last column gives the residual found by subtracting the fourth column from the second.

G. M. T.	Obs. Mag.	A. D.	Curve	O.−C.	G. M. T.	Obs. Mag.	A. D.	Curve	O.−C.
$14^h\ 9^m$	0.50	.068	0.50	.00	$16^h\ 2^m$	0.89	.050	0.97	−8
14 22	0.28	.150	0.50	[−.22]	16 14	1.11	.028	1.05	+6
14 33	0.53	.028	0.50	+ 3	16 33	1.16	.050	1.16	0
14 43	0.51	.045	0.54	− 3	16 45	1.23	.018	1.22	+1
14 55	0.56	.055	0.57	− 1	16 54	1.29	.052	1.26	+3
15 9	0.70	.040	0.65	+ 5	17 1	1.34	.030	1.27	+7
15 17	0.77	.042	0.69	+ 8	17 10	1.26	.065	1.27	−1
15 35	0.86	.060	0.81	+ 5	17 21	1.22	.040	1.27	−5
15 43	0.77	.160	0.87	−10	17 29	1.20	.034	1.27	−7
15 52	0.94	.072	0.93	+ 1					

The average deviations of the individual sets is ±0.057, or, omitting the second group, ±0.052. The corresponding average deviations of the individual groups are ±0.051 and ±0.041. All of these values will be considerably diminished if we use probable errors instead of average deviations.

In conclusion, this form of photometer may be recommended to astronomers having charge of large telescopes as a simple means of determining the brightness of the fainter stars. The star is compared directly with a brighter star without using any intermediate standard. The accidental errors are thus reduced, and since the images exactly resemble each other and may be reversed, almost all forms of systematic errors may be eliminated. Stars as faint as the fourteenth magnitude may be measured with a large telescope with all the accuracy of a brighter star, the average deviations not much exceeding a twentieth of a magnitude. The reduction is simple, and no undetermined constants are involved, the law of variation of the light depending on the fundamental principles of optics. The instrument is portable and easily removed or replaced. It is not difficult by means of it to determine the brightness of any star one to one and one-half magnitudes brighter than the limit of visibility of the telescope employed, with a computed probable error not exceeding three or four hundredths of a magnitude.

As there can be little doubt that the photometric scale of Pogson will eventually come into universal use, photometric measures of the fainter variables, comparison stars, asteroids and satellites are much to be desired.

June 13, 1895.

ON THE FORMS OF THE DISKS OF JUPITER'S SATELLITES.[1]

By S. I. Bailey.

Early in 1894 I attempted to make some observations on the forms of the disks of Jupiter's satellites, using the thirteen-inch refractor of the Arequipa Observatory.

Owing to the exceptional persistency of the cloudy season at that time I was able to observe them on a few nights only, and when Jupiter was low in the western sky.

In Arequipa the seeing after midnight is usually bad, which prevented exact observations toward the close of that year before the beginning of the cloudy season.

During the early months of 1895, however, these satellites were observed under reasonably good conditions. Below are given the dates and times of observation, and a summary of notes. The time given is Arequipa mean time:

January 17, 10:00–12:00 P.M. All four satellites round, except that I, before occultation, appeared elongated in same direction as Jupiter. No change in appearance of II, III and IV. Seeing, 4; scale, 1–5.

January 25, 8:00–10:00 P.M. All four round, except that I, before transit, seemed slightly elongated in same direction as Jupiter, but an hour later in transit looked perfectly round. Seeing, 4.

February 20, 10:00–11:15 P.M. All four apparently elongated slightly in same direction and amount. Seeing, 3–4. Adjustment of lens not perfected since reversal.

March 11, 7:30–10:00 P.M. All four round. No change. Seeing, 4.

March 13, 8:30– 9:10 P.M. II, III and IV in moments of best seeing; round.

March 19, 8:00–10:10 P.M. All four round; no changes.

March 22, 8:00– 9:00 P.M. Through clouds. In best seeing all four round.

March 24, 7:30– 8:40 P.M. Tendency to elongation of all, but round in moments of best seeing. Seeing, 2–3.

[1] Communicated by Edward C. Pickering, Director of Harvard College Observatory.

March 27, 9:00–9:45 P.M. Seeing poor; 2–3. In best seeing, round. II and III close together. Occasional apparent distortion of form shared perfectly by both.

April 13, 7:00–9:45 P.M. All round. Seeing, 2–3.

April 14, 7:00–8:30 P.M. I, II, III and IV round in best seeing.

Consecutive observations for a larger number of hours during any one night were prevented by the clouds which are prevalent during these months.

In nearly all cases my own observations were confirmed by either Mr. H. C. Bailey or Mr. W. B. Clymer, assistants in this Observatory, and sometimes by both.

The results of our observations may be summed up as follows:

Under the best conditions, *i. e.*, with the instrument in perfect adjustment and good seeing, 3–5 on a scale of 1–5, II, III and IV were always seen round. I was twice seen having an apparent elongation in the same direction as Jupiter. In both cases the satellite was near the planet. On the second occasion, January 25, I, when off the disk but near Jupiter, appeared elongated, but an hour later, plainly seen on disk of Jupiter appeared perfectly round. On the other hand the shadows of I and III, on other nights were seen elongated.

Several occultations and transits were observed, but the limb of Jupiter was not seen, when, to me, it gave any indication of transparency.

The power usually employed was 800, but frequently higher and lower powers were also used. The conditions were not considered suitable for work of value, unless the image of a star in focus presented a central circular disk and sharply defined concentric diffraction rings. Under such conditions the components of close doubles, such as Bu 220, could be easily and distinctly separated.

During the hours given above we failed to detect any systematic change of form in any of the satellites. These observations, scattered through the cloudy season, may not be the best possible, for the same observers and instrument, in Arequipa;

nevertheless, it does not seem to me probable that any frequent periodic recurrence of an ellipticity, approximating in amount that of Jupiter itself, would have escaped detection.

Although the above observations were the only ones regarded of special value, it may not be out of place to refer to certain difficulties incidentally met. The thirteen-inch refractor is used for both visual and photographic work. To change from one class to the other it is necessary to remove the lenses and reverse the crown glass. After the use of the lenses for photographic work it is impossible to immediately replace them in perfect position for visual work. The final adjustments require a certain time. When the adjustment is very close, but not perfect, the image of a bright star in focus presents no sensible wings, but the image, when just out of focus, is slightly irregular in form. Under such circumstances I have noticed that if the seeing is good and the images exactly in focus, the disks of the satellites appear round, *i. e.*, are unaffected in form by the slight lack of adjustment,—but, that, with poor seeing or with the images a little out of focus, there is a slight elongation in the same direction as that of the out-of-focus stellar image. The tiring of the eye would, perhaps, have the same effect as a slight change of focus at the eyepiece. When the altitude of the object observed was very low, both in double star and satellite observations, an elongation has been sometimes noticed similar to that caused by lack of adjustment, and perhaps for the same cause. In all such cases, however, the elongation, when present, was shared by all the satellites in common.

AREQUIPA, May 1, 1895.

NOTE ON THE MAGNESIUM BAND AT λ 5007.

By H. Crew and O. H. Basquin.

The interest which a few years ago attached to this feature of the magnesium spectrum has very much abated since Keeler has shown that the normal position of the chief nebular line differs from that of the first edge of the "fluting" by something like half a tenth-meter. At the same time, the prominence of this metal in stellar spectra, and the possible use of its spectrum as a criterion of stellar temperatures make it worthy of study.

Having occasion recently to photograph this part of the magnesium arc spectrum, it was observed, on a preliminary visual examination, that this fluting was made up—the first and second bands at least—of fine lines. Later the fluting was photographed so as to plainly show a linear structure in the third, fourth, fifth and sixth bands also. These lines in the third and following bands are distributed with approximate uniformity at intervals of about half an Ångström unit. They are not, therefore, at all difficult to see or to photograph in the spectroscope which we are using, *viz.*, a Rowland concave grating of ten feet focus—14438 lines to the inch.

At the same time, we have not been able to find, in the literature available, any reference to this fluting having been thus resolved. It seemed, therefore, worth while to measure the wave-lengths of those lines which we could photograph, hoping that some simple law might be found to govern their distribution.

Two sources of light were used, *viz.*, a rotating metallic arc, employing from ten to twenty amperes, and magnesium tape burning in air. It is well known that the fluting is very much stronger (compared with other magnesium lines) in the flame than in the arc. The flame is, therefore, better adapted to the photography of the fluting; while the arc is vastly more convenient for visual work. It is not difficult, however, using the arc, to

photograph the band in the second order provided one cuts out the triplet at λ 3336 with an absorbent in front of the slit, and uses Seed's "double coated" plates.

The following measures are from second-order photographs, the constant being determined from the iron spectrum taken on the same plate. The wave-length of the first head is taken from Rowland's list of standards (*Phil. Mag.* July, 1893), and all the other lines are referred to it. We have assumed, without knowledge, that Rowland's value applies to the maximum of this head rather than to its somewhat uncertain edge. It is thought that, except in the case of two or three very weak lines, the following values are correct to within less than one-tenth of an Ångström unit. The scale of intensities is that of Rowland, as nearly as possible:

Wave-length	Intensity	Remarks	Wave-length	Intensity	Remarks
5007.61		Red edge of first head	4980.11	1	
(5007.473)	6	Maximum of first head	4979.68	1	
4997.03		Red edge of second head	4979.18	1	
4996.92	6	Maximum of second head	4978.73	0	Very weak and hazy
4988.38	1	Five lines immediately preceding third head	4978.07	0	
4988.00	1		4977.70	1	
4987.62	1		4977.23	1	
4987.17	1		4976.75	1	Hazy
4986.77	1		4976.17	1	Hazy
4986.38		Red edge of third head	4975.63	2	
4986.26	6	Maximum of third head	4975.15	2	
4986.02	1		4974.94		Red edge of fourth head
4985.57	1	Wide and hazy	4974.75	5	Maximum of fourth head
4985.11	1		4974.24	1	
4984.68	1		4973.67	0	Rather weak
4984.29	1		4972.98	0	Wide and hazy
4983.72	1		4972.53	2	Group of four quite distinct lines
4983.36	1		4972.04	2	
4982.93	1	Rather hazy	4971.49	2	
4982.43	1	Hazy	4971.00	2	
4981.99	1		4970.44	0	Weak and difficult to measure
4981.55	1				
4981.13	1		4969.79	0	Weak and difficult to measure
4980.56	1				

Wave-length	Intensity	Remarks	Wave-length	Intensity	Remarks
4969.19	2	Group of five distinct lines	4959.09	2	
4968.74	2		4958.48	2	
4968.13	2		4957.91	2	
4967.60	2		4957.48	1	
4967.12	2				Two lines omitted here: too weak to measure
4966.67	0	Wide and hazy			
4966.24	0	Wide and hazy			
4965.83	1		4955.87	0	
4965.13	2		4955.40	0	
4964.60	2		4954.93	0	
4964.10	2		4954.41	1	
4963.50	1	Wide and hazy	4953.82	1	
4962.85	3	Fifth head	4953.17	2	
4962.35	2		4952.62	1	
4961.84	2		4951.93	00	Wide and hazy
4961.37	2		4949.5(?)	0	Sixth head (?)
4960.88	1	Wide			Some twenty weak lines omitted here
4960.35	2				
4959.72	0	Wide and hazy	4935.17	2	Seventh head (?)

It will be seen from the above table that the distance between consecutive lines tends to increase, as one recedes from the head, very much after the manner of the lines in a carbon band.

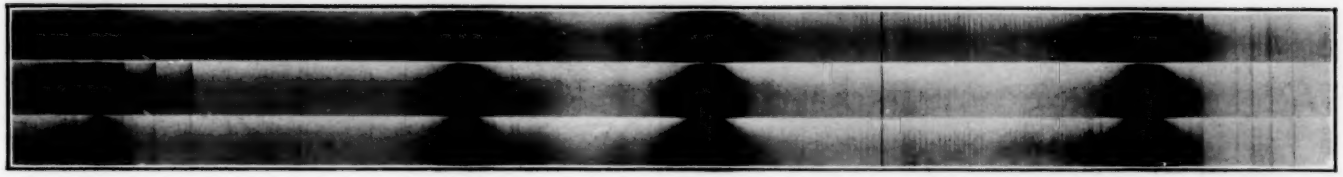
In the following table are grouped the wave-lengths of the various heads. The value for the sixth is uncertain on account of its weakness, and on account of companion lines quite as strong as itself. The seventh is comparatively strong, but may represent an individual magnesium line instead of a "head," or it may be an impurity:

Head	Wave-length	Difference
First,	(5007.473)	
		10.55
Second,	4996.92	
		10.66
Third,	4986.26	
		11.51
Fourth,	4974.75	
		11.90
Fifth,	4962.85	
		13.40
Sixth,	4949.50	
		14.30
Seventh,	4935.17	

NORTHWESTERN UNIVERSITY,
Evanston, Ill., June 10, 1895.

PLATE VII

λ4216 λ4737



A CARBON-CYANOGEN SPECTRUM PLATE

(a) CO_2 in Mg arc, atmosphere CO_2
(b) CO_2 in Mg arc, atmosphere air and CO_2
(c) CO_2 in Mg arc, atmosphere CO_2

NOTE ON THE SPECTRUM OF CARBON.

By H. Crew and O. H. Basquin.

Since the year 1889, it has been customary to assign the three carbon bands at λ 4216, λ 3883 and λ 3590 to cyanogen. The most conclusive evidence for this view was furnished by Kayser and Runge in their well-known paper. (*Wied. Ann.* **38**, 80–90, 1889.) The surprise which these investigators felt, and frankly expressed, at their own results has doubtless been shared by each of their readers. The fact that a compound of carbon and nitrogen not only persists but actually forms at the temperature of the carbon arc is sufficiently surprising in itself; but when the same compound, or at least the same group of lines, is found in the solar spectrum, the fact is truly astonishing. Indeed, these results are so much at variance with the ordinary facts of dissociation at high temperatures that some have fairly hesitated to accept the view of Kayser and Runge.

It has seemed to us, therefore, that the following somewhat independent evidence for the existence of cyanogen in the carbon arc might not be without interest. It occurred to us that *if the spectrum of carbon could be obtained by the introduction of carbonic acid gas into a metallic arc*, that then nitrogen might be easily and thoroughly mixed with the CO_2 and its effect determined at once.

The experiment was tried as follows: A rotating arc (described in *Phil. Mag.* October, 1894) was fitted with "chemically pure" magnesium poles. The fixed electrode had a hole drilled through it lengthwise, so that the gas could be introduced at one end while the arc was formed at the other. The whole was then enclosed in an air-tight metal box cast in two pieces and screwed together with wide flanges. This metallic hood was fitted with three stopcocks. Through one of these the CO_2 could be led into the fixed electrode and thence directly into the middle of the arc; through a second, the gas could be introduced into the hood as an atmosphere surrounding the arc;

the third was used as an escape pipe. The gas was supplied from an iron drum of liquid CO_2.

As to results, it may be stated first of all that this proved to be a convenient method of producing a very pure carbon spectrum. Copper, tin, and some other metals were tried, and found to behave very much as magnesium, that is they all act, apparently, as reducing agents, furnishing free carbon at the poles. Iron, however, acts very feebly as compared with magnesium.

In order to observe both carbon and cyanogen bands under identical conditions, a photographic plate was so placed as to include both λ 4216 and λ 4737 in the second order of a concave grating of ten feet radius.

A stream of CO_2 was introduced into the hood surrounding the arc, thus displacing the air; and the spectrum of the arc was then photographed. *The band at λ 4737 came out very distinctly, while that at λ 4216 was scarcely visible.*

By means of a footbellows a current of air, in addition to the CO_2, was next introduced into the hood, but not immediately into the center of the arc, and the spectrum again photographed on an adjoining portion of the same plate, no circumstance having been changed except by the introduction of the air.

The effect of the air was to multiply many fold the intensity of the band at λ 4216, while that at λ 4737 was very much weakened. But the change in the band at λ 4737 was not nearly so marked as that at λ 4216. To insure the constancy of all conditions except that of the atmosphere surrounding the arc, a third photograph was taken after the current of air had been shut off for a few seconds, the CO_2 still running. In this interval of time, the stream of CO_2 had sufficiently cleared the hood of air to cause the band at λ 4216 to disappear, the first and third photographs being identical.

The bands at λ 3590 and λ 3883 were found to behave exactly as that at λ 4216. The bands λ 5165 and λ 5635 were examined visually. While the CO_2 was streaming through the hood, the observer at the eyepiece, by means of a rubber tube, blew a current of air from his lungs either into the hood or into the arc.

The effect was to diminish the intensity of the bands at λ 5165 and λ 5635 in the most striking manner; indeed, they practically disappeared the instant the air was introduced. The same is true when dry (?) air is introduced by the bellows. At first glance one might think that the effect of this air was merely mechanical, sweeping away the CO_2 from the arc; but on looking at the band at λ 4216 one sees it very bright, showing that there is plenty of carbon at the poles. The band at λ 4382 is more difficult to observe; but the photographs show that it, too, is carbon, and not cyanogen.

By means of this hooded arc and magnesium poles, we have succeeded in getting some very distinct photographs of the cyanogen band at λ 4606.

As this band is mentioned, but not measured, by Kayser and Runge, we have determined the wave-lengths of the various heads. We think the values of the following table may be found in error at any point by, perhaps, one twentieth of an Ångström unit.

The scale of each plate was determined from iron lines found in Rowland's table of standards.

All the following values are referred to his value for the very sharp blue magnesium line λ 4571.281:

Head	Wave-length	Difference
First,	4606.33	
		28.14
Second,	4578.19	
		24.88
Third,	4553.31	
		21.25
Fourth,	4532.06	
		17.11
Fifth,	4514.95	
		12.60
Sixth (?)	4502.35 (?)	

The band at λ 3300 we have not succeeded in finding. The result of this experiment is then to confirm, at every point, the work of Kayser and Runge.

NORTHWESTERN UNIVERSITY,
Evanston, Ill., June 10, 1895.

THE MEASUREMENT OF SOME STANDARD WAVE-LENGTHS IN THE INFRA-RED SPECTRA OF THE ELEMENTS. II.

By EXUM PERCIVAL LEWIS.

SINCE the writing of the article on this subject which appeared in THE ASTROPHYSICAL JOURNAL for June, investigations of the infra-red spectra of calcium, strontium, and thallium have been carried on with the radiomicrometer. The results are given below:

CALCIUM.

8541.48	8661.38
8541.55	8661.49
8542.92	8662.82
8542.28	8662.63
8541.10	8661.47
8541.9	8662.0

H. Becquerel observed a band of calcium lines between wave-lengths 8580 and 8760. A thorough search was made of this region, without detecting any evidence of other lines.

These lines are probably coincident with those given in Abney's table of the solar spectrum as 8541.8 and 8661.4.

STRONTIUM.

I	II
10325.72	10326.00
10326.66	10327.21
10326.91	10327.35
10326.79	10327.46
10327.30	10327.71
10326.93	10326.11
10326.72	10326.97

Average, 10326.8

I	II
10914.20	10915.70
10916.95	10914.35
10914.77	10915.13
10917.56	10915.27
10915.82	10915.40
10916.07	10915.66
10915.89	10915.25

Average, 10915.6

Becquerel gives the wave-lengths 10340 and 10980 for these lines.

THALLIUM.

11510.39
11512.66
11512.38
11511.66
11511.51

11511.7

This line was very diffuse, covering a space of about 10 Ångström units. The above result may, therefore, be in error by several Ångström units. Becquerel gives 11500 as its wave-length.

Below is a summary of the results so far obtained in this investigation, with a comparison of the intensities of the lines,

Element	Wave-length	Intensity
Ca	7663.7	30
Ag	7688.4	25
Li	8126.3	40
Na	8183.7	60
Na	8194.2	60
Ag	8274.0	25
Ca	8541.9	50
Ca	8662.0	50
Sr	10326.8	40
Sr	10915.6	45
Na	11381.1	35
Na	11403.9	35
Th	11511.7	40

the intensity of the D lines being taken as 60. On account of irregularities of the arc due to the impossibility of maintaining a uniform supply of the salt, these intensities must be considered as only approximately correct.

Unsuccessful search was made for the lines which appear in Becquerel's list as follows:

Potassium,	10980, 11620, 12330.
Strontium,	8700, 9610, 10030.
Magnesium,	8990, 10470.
Lead,	10598, 10870, 11330, 12210, 12290.

Lines predicted as follows by Kayser and Runge were not found:

Mercury,	9497.
Magnesium,	13007, 13041, 13111.
Calcium,	11801, 11874, 12020.
Strontium,	13022, 13345, 14086.

JOHNS HOPKINS UNIVERSITY,
June, 1895.

PRELIMINARY TABLE OF SOLAR SPECTRUM WAVE-LENGTHS. VII.

By HENRY A. ROWLAND.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
4903.896		0000	4913.980		000 N
4904.350		000	4914.150		2
4904.597		3	4914.401		0000
4905.009		0000	4914.583		0000
4905.310	Fe?	0	4914.702		0000
4905.981		000 N d?	4915.414	Ti	000
4906.316		000	4915.952		0000
4906.578		0000	4916.026		0000
4906.885		0000	4916.426		000
4906.952	Cr	000	4916.660		00
4907.232		0000 N	4916.852		0000
4907.494		0000	4917.028		0000
4907.681		0000	4917.134		0000
4907.918	Fe	2	4917.410	Fe	2
4908.209		0 N	4917.529		0000
4908.450		0000	4918.004		000
4908.673		000	4918.190	Fe	1
4908.784		000	4918.349		0000
4909.012		0000	4918.543	Ni	2
4909.283		000	4918.886	Ni	0
4909.377		0000	4919.174 s	Fe	6
4909.566	Fe	2	4919.482		0000
4909.888		000	4919.624		000
4910.198	Fe	3	4919.923		000
4910.505	Fe	2	4920.047		00
4910.753	Fe	2	4920.241		0000
4910.952		000 N	4920.474		0000
4911.205		000	4920.685 s	Fe	10
4911.374		1	4920.862		000
4911.568		000	4921.147	La	0
4911.717		0	4921.344		0000
4911.963	Fe	1	4921.577		0000
4912.199	Ni	1	4921.774		0000
4912.362		0000	4921.963	La Ti	1
4912.666		000	4922.164		0000
4912.964		0000	4922.336	Ni	000
4913.157		000	4922.446	Cr	2
4913.311		00	4922.665		0000
4913.450		0000	4922.842		0000
4913.803	Ti	2	4922.995		000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
4923.155		0000	4938.150		0000
4923.329	Fe?	00	4938.350	Fe	2
4923.540		000 d	4938.467		000
4923.813		0000 d	4938.997	Fe	4
4924.107 s	Fe	5	4939.416	Fe	2
4924.299		0000	4939.654		0000
4924.478		00	4939.868	Fe	3
4924.764		000	4939.998		0000
4924.956 s	Fe	3	4940.152		0000
4925.140		0000	4940.257		000
4925.261		0000	4940.669		000
4925.450	Fe	00	4940.885		0000Nd?
4925.594		000	4941.132		0000
4925.746	Ni	1	4941.391		0000
4926.334		000	4941.496		0000
4926.577		0000 N	4941.752		0000
4926.873		000	4942.002		0000
4927.022		000	4942.083		0000
4927.123		0000	4942.660	Cr	2
4927.447		000	4942.774		000
4927.601	Fe	1	4943.480		0000
4927.650		0000	4943.623		0000
4927.842		0000 N d?	4944.087		0000
4928.050	Fe	2	4944.467		00
4928.297		0000 d	4944.751		000
4928.511	Ti	0	4945.457		0000
4930.241		000	4945.622	Ni	1
4930.486	Fe	2	4945.814	Fe	1
4930.655		0000	4946.215	Ni	0
4930.977	Ni	00	4946.344		0000
4931.296		000	4946.568	Fe	3
4931.911		0000	4947.778		00
4932.194		000	4948.120		0000
4932.246	Ni	0	4948.368		000
4933.367		0	4948.520		000
4933.514	Fe	2	4948.773		0000 N
4933.847		000 N d?	4949.753		0000
4934.054	Fe	0	4950.291	Fe	2
4934.214 } s	Ba	3	4950.555		0000 N
4934.277 }		4	4950.801		0000 N
4935.048		0000	4951.606		000
4935.595		000	4952.461	Fe	1
4935.827		0000	4952.635		0000
4936.015	Ni	2	4952.823	Fe	2
4936.512	Cr	1	4953.015		0000 N
4936.876		0000	4953.197		0000 N
4937.245		00	4953.392	Ni	2
4937.524	Ni?	3	4953.612		0000 N
4937.705		0000	4953.807		000 N
4937.902	Ti	000	4954.179		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
4954.472		0000	4971.531	Ni-	1
4954.782	Fe	1	4972.096		0000 N
4954.986	Cr	2	4972.357		0000
4956.152		000	4972.572		0000
4956.922		0000	4972.832		0000 N
4957.480 s	Fe	5	4973.088		0000
4957.650		0000	4973.281 s	Ti-Fe	4
4957.785 s	Fe	8	4973.533		0000
4957.878		000	4973.827		0000
4958.207		0000	4974.431		000
4958.431	Ti	00	4974.537		0000
4959.320		0000	4974.642		0000
4959.381		00	4974.728		0000
4960.526		0000	4975.530	Ti	00
4961.039		0000	4975.588	Fe	00
4961.235		00	4975.729		0000
4961.564		0000	4976.314	Ni	0
4962.095		0	4976.508	Ni	1
4962.298		0000	4976.671		0000
4962.467	Sr?	000	4976.868		000
4962.751	Fe	2	4977.056		0000
4962.905		0000	4977.833	Fe	0
4963.087		0000	4977.891		0000
4963.245		0000	4978.104		0000 N
4963.725		0000	4978.289		000
4964.312		000	4978.372	Ti	00
4964.903	Ti	000	4978.544		0000
4965.107	Cr	1	4978.732 } s		0
4665.351	Ni	0	4978.785 }	Fe	3
4965.580		0000	4978.863		0000
4965.986		0000	4979.112		0000
4966.036	Mn	00	4979.232		0000
4966.270	Fe	4	4979.391		000
4966.460		000	4979.485		0000
4966.761		0000	4979.767	Fe	00
4966.979		0000	4979.885		0000
4967.449		0000	4980.012		0000
4967.571		0000	4980.143		0000
4967.700	Ni	00	4980.352 s	Ni-	4
4967.859		0000	4980.477		000
4968.080	Fe	3	4980.723		000
4968.569		00	4981.453		0000
4968.769	Ti	0	4981.550		000
4968.880	Fe	1	4981.912 s	Ti	4
4969.028		0000	4982.319		000
4970.098	Fe	3	4982.682	Fe	4
4970.291		0000	4982.994		2
4970.382		0000	4983.205		0000
4970.671	Fe	1	4983.433	Fe	3
4970.829		0	4983.644		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
4983.777		0000	4998.742		0000
4984.028	Fe	3	4999.141		0000
4984.297	Ni	2	4999.297	Fe	0
4984.476		0000	4999.439		0000
4984.632		0000	4999.689 s	Ti, La	3
4984.806		00	5000.388		000
4985.432	Fe	3	5000.526	Ni	2
4985.730	Fe	3	5000.721		0000
4985.941		0000	5000.917		000
4986.165	Cr	00	5001.165	Ti	0
4986.403	Fe	1	5001.387		0000
4987.088		00	5001.654		000
4987.260		0000	5002.044	Fe	5
4987.452		0000	5002.510		0000
4987.610		0000	5002.771		0000
4987.827		0000	5002.976	Fe	2
4988.030		0000	5003.924	Ni	0
4988.313		000	5004.056		0000
4988.535		0000	5004.226	Fe	0
4989.130	Fe	2	5004.393		0000
4989.325	Ti	00	5004.547	Cr	000 d
4989.730		0000	5005.068		00
4990.147		000	5005.347	Mn	0
4990.625	Fe	0	5005.581		000
4991.247	Ti	3	5005.675	Pb?	0000
4991.452	Fe, La	2	5005.896 s	Fe	4
4992.036		00	5006.306 s	Fe	5
4992.252		0000 N	5006.556		000
4992.461		000	5006.709		000
4992.657		0000	5006.870		000
4992.962		000	5007.398 } s	Ti	3
4993.173		0000	5007.461 }	Fe	2
4993.531		0	5007.912		00
4993.699		0000	5008.217		0000
4993.864	Fe	0	5008.409		0000
4993.926		000	5008.632		0000
4994.114		0000	5008.825		000
4994.316 s	Fe	3	5009.370		0000
4995.208		0000 N d?	5009.604		000
4995.586		00	5009.829	Ti, Co	00
4995.835		00	5010.006		0000 d?
4996.050		0000	5010.199	Ni	0
4996.375		0000	5010.396		00
4996.558		000	5010.506		000
4996.812		0000	5011.119	Ni	0
4997.024	Ni	1	5011.384		000
4997.161		0000	5012.252	Fe	4
4997.283	Ti	0	5012.335		1
4998.139		000 N	5012.490		0000
4998.408	Ni	1	5012.625	Ni	1

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5012.773		0000	5024.403		000
5012.875		0	5025.027	Ti	3
5013.479	Cr, Ti	2	5025.256	Ni	00
5013.644		0000	5025.482		00
5013.871	Ti	0	5025.749	Ti	1
5013.953		0000	5025.938		000
5014.100		00	5026.086		0000
5014.236		000	5026.670		0000
5014.369 } s	Ti	2	5027.305	Fe	3
5014.457 }	Fe	3	5027.406		00
5015.123	Fe	3	5027.531		000
5015.304		0000	5027.707		0000
5015.476		000	5027.798		0000
5016.220		000	5027.939	Fe	1
5016.340	Ti	2	5028.101		0000
5016.504		0000	5028.308	Fe	2
5016.659		00	5028.537		000
5016.864		0000	5028.719		0000
5017.060	Fe	0	5029.660		0000
5017.228		0000	5029.805	Fe	1
5017.370		0000	5029.994		000
5017.562		0000	5030.096		0000
5017.762	Ni	3	5030.218		0000
5017.997		000	5030.817		000
5018.210		0000 N	5030.960		00
5018.463	Ni	1	5031.058		0000
5018.629	Fe	4	5031.199		3
5019.059		0000 N	5031.361		000
5019.364		000	5031.939		0000
5019.664		0000	5032.092		00
5019.912		00	5032.252		0000
5020.208 s	Ti	2	5032.560		000 N
5020.675		000	5032.912	Ni	00
5020.873		0000	5033.305		0000 N
5020.998		00	5033.714		000
5021.177		000	5033.835		000
5021.328		0000	5033.960		000
5021.778	Fe	0	5034.354		000
5021.869		000	5034.530		0000
5022.108	Cr	000	5035.542	Ni	5
5022.240		0000	5035.846		000 Nd?
5022.414	Fe	3	5036.089 } s	Ti	3
5023.052	Ti	2	5036.155 }	Ni	2
5023.221		0000	5036.332		0000
5023.372	Fe	0	5036.449	Fe	0
5023.531		0000	5036.645	Ti	2
5023.674	Fe	0	5036.909		0000Nd?
5023.819		0000	5037.105	Fe	00
5024.010		000	5037.375		0000
5024.190		0000	5037.496		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5037.669		0000	5049.769		0000
5037.885		000	5049.860		0000
5037.983		000	5050.008 s	Fe	6
5038.579	Ti	2	5050.316		000
5038.774	Ni?	2	5050.626		000
5038.974		0000	5050.751		0000
5039.065		000	5050.919		000
5039.239		000	5051.145		00
5039.428	Fe	3	5051.488		000 N
5039.542	Ni	00	5051.683	Ni	1
5039.683		0000	5051.825	Fe	4
5039.951		000	5052.084	Cr	0
5040.138	Ti	3	5052.338		0 N
5040.300		0000	5052.803		00
5040.422		000	5052.917		0000
5040.644		0000	5053.056	Ti	0
5040.787	Ti	00	5053.170		00
5040.908		0000	5053.301		0000
5041.069	Fe	3 d?	5053.477		000
5041.255	Fe	4	5053.756		00 N
5041.499	Ti	00	5054.261		000
5041.633		00	5054.821	Fe	1
5041.795 s	Ca	2	5055.762		000
5041.936	Fe	4	5055.975		0000
5042.033	Ni	00	5056.169	Fe	00
5042.200		0000	5056.307		000
5042.367	Ni	1	5056.428		000
5043.475		000	5056.617		000
5043.761	Ti	00	5057.021	Fe	1
5043.885		0000	5057.665	Fe, Ni	0
5044.011		0000	5057.875		0000
5044.212		000	5058.017		000
5044.394	Ni, Co-Fe	3	5058.167	Fe	1
5044.945		0000 N	5058.421		000 N
5045.454		00	5058.674	Fe	00
5045.582	Ti	00	5058.989		0000
5046.379		000 N	5059.110		0000
5047.107		000	5059.409		000
5047.301		000	5059.575		0000
5047.483		000 d	5059.964	Co	00
5047.726		0000	5060.111		0000
5047.898		0000	5060.258 s	Fe	3
5048.120		00	5060.476		0000
5048.242	Ni	0	5061.575		000
5048.409		00 N d	5061.703		000
5048.612	Fe	3	5061.882		00
5049.035	Ni-	2	5062.066		000 N
5049.192		0000	5062.285	Ti	0
5049.384		0000	5062.530		0000
5049.607		0000	5063.355		00

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5063.479		000	5074.932	Fe	5
5063.699		0000	5075.154		0000
5063.927		0000	5075.341		0000
5064.058		0000	5075.480	Ti	00
5064.244	Ti	00	5075.716		0000
5064.557		0000 N	5075.989		0000
5064.836 s	Ti	3	5076.277		000
5064.989		0000	5076.450	Fe	3
5065.152		1	5076.504		000
5065.207	Fe	3	5076.666		0000
5065.380	Fe	2	5076.807	Ti	00
5065.556		0000	5076.950		000
5065.890		0000	5077.562		000
5066.078	Cr	000	5077.780		0000
5066.174	Ti	000	5078.013		0000 d
5066.446		0000	5078.246		000
5066.545		0000	5078.541		000
5066.908		00	5078.719		0000
5067.039		000	5078.891		0000
5067.336	Fe	3	5079.158	Fe	3
5067.679		000 N	5079.409	Fe	4
5067.874	Cr	0	5079.732		0000
5067.954	Co	000	5079.921	Fe	4
5068.485	Cr, Ti	0000	5080.144	Ni	1
5068.944 s	Fe	5	5080.288		0000
5069.267		000	5080.505		00
5069.592	Ti	000 d	5080.714	Ni	4
5069.802		0000	5080.966		0000
5069.971		0000	5081.111		0000
5070.165		00	5081.286	Ni	3
5070.313		000	5081.534		0000 N
5070.471		0000	5081.764		000
5070.615		0000	5081.942		000
5071.098		000	5082.019		000
5071.311		000	5082.231		0000
5071.435		0000	5082.363		0000
5071.666	Ti	0	5082.526	Ni	2
5071.969		000 N	5082.829		0000
5072.032		0000	5083.071		0000
5072.257	Fe	3	5083.205		000 Nd?
5072.479	Ti	0	5083.365		0000
5072.650		0000	5083.518 s	Fe	4
5072.849	Fe	2	5083.709		0000
5073.114	Cr	1	5083.877		000
5073.348		0000	5084.038		000
5073.637	Ti	00	5084.279	Ni	3
5073.776		0000	5084.590		0000
5073.924		000	5084.734		000
5074.244		0000 N	5084.876		000
5074.521		000	5085.017		000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5085.179		0000	5096.215		0000
5085.341	Ti	0000	5096.357		000
5085.513		000	5096.660		0000
5085.668		0	5096.762		0000
5085.856		000	5096.908		000
5086.078	Cd?	0000 N	5097.038 } s	Ni	0
5086.422		00	5097.175 }	Fe	3
5086.570		000	5097.489		000
5086.794		0000	5097.658		0
5086.947		000	5097.884		0000
5087.104		0000	5098.046		0000
5087.239	Ti	0	5098.302		00 N
5087.432		0000	5098.492		000 N
5087.601	Y?	1	5098.751	Fe	1
5088.019		0000 N	5098.885	Fe	3
5088.175		000	5099.104		0000 N
5088.331		0	5099.251	Fe	0
5088.719	Ni	0	5099.497	Ni	1
5088.929		0000	5099.744		0000 N
5089.134	Ni	0	5099.957		000
5089.387		000 N d?	5100.108	Ni	2
5089.541		0000	5100.413		0000
5090.004		0000	5100.636		0000
5090.236		0000 N	5100.827		00
5090.391		000	5101.028		000
5090.569		0000	5101.108		000
5090.954 s	Fe	5	5101.251		000
5091.146	Cr	0000	5101.445		0000
5091.353		0000	5101.655		000
5091.477		0000	5101.790		0000
5091.662		0000	5101.994		0000
5091.896		000	5102.184		0000
5092.058		00	5102.410		0000
5092.285		0000	5102.599		000
5092.483		00	5102.843		0000
5092.665		0000	5103.142	Ni	1
5092.977		000	5103.297		0000
5093.220		0000	5103.567		000
5093.513		0000	5103.721		0000
5093.623		0000	5103.909		000
5093.858		0000 N	5104.083		0000
5094.199		000 N	5104.204	Fe	0
5094.594	Ni	0	5104.366		0
5094.789		0000	5104.614		0
5095.117		00	5104.817		0000
5095.348		00 d?	5105.066		000
5095.512		00	5105.260		0000
5095.679		0000	5105.356		0000
5095.840		0000	5105.536		000
5096.031		000	5105.718 s	Fe	4

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5105.918		0000	5117.071		000
5106.183		0000 N	5117.334		0000
5106.407		0000	5117.933		0000
5106.556		0000	5118.112	Mn	00
5106.623		000	5118.241		0000
5106.773		000	5118.352		0000
5107.047		0000	5118.529		0000
5107.619	Fe	4	5118.987		000 Nd?
5107.823	Fe	4	5119.292		00
5108.056		000	5119.368		0000
5108.149		0000	5119.555		000
5108.359		000	5119.820		0000
5108.563		00	5119.942		0000
5108.805		0000	5120.084		0000
5109.083		0000	5120.276		0000
5109.291		000 d?	5120.516		000
5109.475		0000	5120.592	Ti	0
5109.601	Ti	0000	5120.802		000
5109.827 s	Fe	2	5120.893		0000
5110.188		0000	5121.056		0000
5110.574 s	Fe	5 d	5121.197		0000
5110.938	Cr	00	5121.399		0000
5111.138		0000	5121.609		0000
5111.426		0000	5121.732 } s	Ni	0
5111.539		000	5121.825 } s	Fe	2
5111.802		000	5122.156		0000
5111.912		0000	5122.299	Cr	000
5112.049		000	5122.481		0000
5112.458		000	5122.613		000
5112.663		0000	5122.968	Co	000
5112.817		0000 N	5123.178		000
5112.944		0000	5123.390	Y	0
5113.153		000	5123.458		0000
5113.298	Cr	00	5123.641	Cr	000
5113.424		0000	5123.899	Fe	3
5113.617	Ti	0	5124.219		000
5113.920		0000	5124.364		0000
5114.195		0000 N	5124.560		000
5114.431		000 N d?	5124.785		00
5114.683		000 N d?	5124.939		0000
5115.367		0000	5125.300	Fe	3
5115.566 s	Ni	2	5125.423	Ni	1
5115.843		0000	5125.645		0000
5115.961	Fe	0	5126.012		0000
5116.045		0000	5126.167		0000
5116.217		0000	5126.371 s	Fe-Co	2
5116.359		0000	5126.680		000
5116.643		0000	5126.856		000
5116.849		0000	5127.035		000
5116.944		000	5127.187		0000

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
5127.360		0000	5138.036		0000
5127.533 s	Fe, Ti	3	5138.130		0000
5127.858		00	5138.279		0000
5128.051		0000	5138.518		0000
5128.250		000	5138.690		0000
5128.382		0000	5138.890		000
5128.486		0000	5139.037		0000
5128.660		000	5139.189		0000
5128.807		0000	5139.427 s	Fe	4
5129.080		000	5139.644 s	Fe	4
5129.336	Ti?	3	5139.817	Cr	00
5129.546	Ni	2	5140.094		0000
5129.805	Fe	1	5140.336		0000
5129 990		0000	5140.553		0000
5130.110		0000	5140.992		00
5130.304		0000	5141.193	C?	0000
5130.543	Ni	00	5141.386	C,-	000
5130.757		000	5141.497		0000
5131.103		0000	5141.709		0000
5131.478		000	5141.918 s	Fe	3
5131.642	Fe	2	5142.074		0000
5131.771	C	0000	5142.279		0000
5131.942	Ni	1	5142.458		0000
5132.338		0000	5142.693	Fe	4 d?
5132.523		000	5142.958 s	Ni	2
5132.673		000	5143.111 s	Fe	3
5132.843		00	5143.288		0000
5133.118		000	5143.511		000
5133.209		0000	5143.764		000
5133.364		000	5143.901		00
5133.654		000	5144.031		0000
5133.870 s	Fe	4	5144.203		0000
5133.988	C	0000 N	5144.543		000 N
5134.505		0000	5144.758	C,-	000
5134.697		000	5144.847	Cr, C	00
5134.849		0000	5145.098		0000
5135.273		0000	5145.271	Fe	1
5135.355		0000	5145.403		0000
5135.752	C,-	000	5145.636	Ti	0
5135.880	C,-	000	5145.907		0000 N
5136.103		0000	5146.291	C,-	00
5136.270	Fe	00	5146.486		000
5136.443		000	5146.659 s	Ni-	3
5136.625		0000	5146.945	Co	000 d?
5136.835		0000	5147.273		000
5136.969		000	5147.458		0000 N
5137.250	Ni	3	5147.652	Ti	0
5137.558	Fe	3	5147.871	C,-	000
5137.753	C,-	000	5147.992	C,-	000
5137.864	C,-	000	5148.222	Fe	2

188

RÉSUMÉ OF SOLAR OBSERVATIONS MADE IN 1894 AT THE ASTROPHYSICAL OBSERVATORY OF CATANIA.

By A. MASCARI.

HONORED by Professor A. Riccò, Director of the Observatory of Catania, with the task of continuing his long and important series of solar observations made at Palermo from 1880 to 1890, and at Catania in 1891 and 1892, I have endeavored to follow his methods in order to render the new series in all respects comparable and homogeneous with the first.

The observations of the spots and faculæ are made with an equatorial telescope having a clear aperture of $0^m.33$. An image of the Sun $0^m.57$ in diameter is projected upon a screen, where the outlines of the spots are traced.

When the spots have been drawn and their positions determined the position angles of the various groups of faculæ visible near the Sun's limb are measured. These are classed according to their brightness as very faint, faint, bright, very bright. The number of these observations is always much inferior to that of spots, because they are made only when the conditions are very favorable. This is made necessary by the fact that the visibility and brightness of the faculæ are much affected by atmospheric conditions and by unsteadiness of the solar image.

The prominences are observed by means of a spectroscope with Rutherfurd grating attached to the same telescope. All elevations observed at the limb which have a height of not less than $30''$ are classed as prominences. Those of less height are classed as *jets* or as belonging to the chromosphere.

While these observations are being made the observing-room is kept in darkness by means of a curtain attached to the shutter of the dome, with the further protection of a large screen attached to the objective of the telescope. Thus the observer

and the screen on which the image is projected are shielded from all foreign light, and it becomes possible to distinguish the granulation of the photosphere without difficulty, to follow very frequently groups of faculæ to a distance of nearly one-third of a radius from the limb, and to detect such as occur in high heliographic latitudes and in the region of the poles.

The reduction to heliographic latitude of the position angles obtained for the faculæ and prominences is made rapidly and

TABLE I.

Day of month	January					February					March				
	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences
1	12	16	98	10	8	7	5	21	8	8	7	9	20	9	5
2	..	..	..	..	..	8	10	22	7	6	4	5	11	10	5
3	7	13	29	..	..	8	8	42	5	5	7	3	17	9	2
4	6	11	49	7	..	5	11	33	..	.	5	2	9	8	1
5	7	10	35	..	..	6	10	51	9	7	4	2	18	..	.
6	9	9	50	7	4	..	..	..	..	.	5	2	33	..	.
7	7	5	57	6	..	7	15	66	..	4	5	5	24	6	4
8	4	3	21	..	..	10	16	58	10	6	4	6	8	..	.
9	6	6	27	7	5	8	11	87	12	6	6	6	38	6	.
10	5	7	17	..	..	10	15	98	11	3	8	10	53	..	.
11	8	10	45	10	4	9	10	83	12	4	8	8	92	8	4
12	8	13	44	6	10	8	10	63	..	9	7	8	46	10	5
13	..	..	..	..	..	11	10	67	..	6	.	..	..	..	.
14	..	..	..	..	..	8	8	26	..	8	6	10	34	..	.
15	9	15	52	..	4	8	9	12	..	6	.	..	..	..	.
16	10	16	93	9	8	..	..	..	..	.	6	5	16	6	.
17	10	16	130	9	5	9	7	24	6	4	3	4	3	..	2
18	11	11	153	10	4	6	7	64	..	.	7	5	8	11	5
19	13	15	133	8	7	..	..	..	..	.	.	..	..	..	.
20	14	16	103	13	5	..	..	..	..	.	5	5	3	..	.
21	12	12	89	9	5	..	..	..	..	.	5	5	8	..	5
22	13	12	38	6	3	..	..	..	..	.	2	3	6	..	.
23	11	11	31	..	5	..	..	..	..	.	6	6	34	11	7
24	10	12	18	..	..	7	13	37	..	.	2	3	27	..	.
25	12	14	66	14	..	7	8	57	10	.	2	6	25	..	6
26	11	22	65	..	..	11	12	43	..	3	3	6	10	..	.
27	..	..	..	..	..	8	11	18	..	.	6	7	34	6	8
28	5	12	58	..	3	7	11	17	10	2	8	14	14	..	8
29	8	7	41	..	4	..	..	..	..	.	7	12	27	..	5
30	8	5	34	9	4	..	..	..	..	.	.	..	..	..	.
31	5	5	22	..	7	..	..	..	..	.	7	14	53	..	.

TABLE I. (*Continued.*)

Day of month	April					May					June				
	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences
1	6	12	56	.	4	..	..	..	..	.	7	11	45	5	0
2	.	..	..	.	.	8	13	22	..	.	10	10	44	..	3
3	7	12	69	7	2	9	14	56	..	4	9	10	37	10	1
4	7	13	16	.	.	8	16	42	..	2	10	13	45	..	1
5	9	14	45	.	.	8	11	83	..	3	11	13	38	..	2
6	6	19	16	.	.	7	9	55	7	2	..	..	..	..	..
7	6	16	55	.	5	7	12	58	9	1	..	..	..	..	..
8	5	11	45	.	4	..	..	..	..	.	..	..	..	..	..
9	.	..	..	.	.	7	12	54	8	.	8	20	66	..	..
10	5	11	25	.	4	6	10	33	8	4	8	17	47	..	3
11	3	7	20	4	4	6	9	24	11	3	9	19	79	7	5
12	.	..	..	9	.	7	11	31	..	4	8	17	96	..	7
13	4	9	33	.	9	5	13	33	..	.	..	..	..	..	..
14	3	10	26	.	3	6	16	54	8	4	10	17	82	3?	2
15	4	9	36	.	2	6	16	93	..	8	10	17	64	..	6
16	2	5	5	8	.	6	14	128	7	5	11	23	121	8	5
17	2	4	21	.	6	7	15	100	..	3	10	17	90	9	5
18	3	5	13	9	.	9	24	61	..	4	8	21	77	9	3
19	.	..	..	.	.	9	23	107	..	.	10	17	42	7	3
20	.	..	..	.	.	8	27	36	..	3	8	11	34	6	5
21	8	8	56	.	5	6	23	94	8	3	7	15	50	7	2
22	8	17	65	8	2	7	22	44	..	5	7	17	29	12	5
23	.	..	..	8	.	7	19	73	..	5	7	14	20	8	4
24	9	12	34	.	6	7	17	59	..	3	7	6	52	10	3
25	8	16	28	.	3	6	12	21	..	.	6	7	23	..	7
26	7	16	47	.	3	..	..	..	..	.	6	6	37	8	8
27	6	13	33	.	6	6	9	38	10	7	4	4	9	..	13
28	.	..	..	.	.	9	6	47	7	9	7	8	39	7	9
29	.	..	..	.	.	10	9	39	10	6	7	10	42	13	7
30	.	..	..	.	.	..	..	..	..	.	7	5	33	..	..
31	.	..	..	.	.	..	..	..	..	.	..	..	..	..	..

with a sufficient degree of approximation by means of the tables prepared by Professor Riccò.[1]

With these means the spots were observed in 1894 on 312 days, the faculæ on 173 and the prominences on 247. In Table I are given for each day of observation the total number of faculæ, of prominences and of groups of spots and pores, together with the number of spots and the number of pores of

[1] "Tavole per trovare prontamente la latitudine eliografica d'un punto del bordo solare di cui sia noto l'angolo di posizione."—*Mem. Spettr. Ital.* 10.

which these groups were composed. In Table II all the faculæ and prominences grouped by quarters are distributed in zones 10° wide in the northern and southern hemispheres. Table III gives the mean frequency of each of these phenomena.

During the year the Sun was seen free from spots (and with only a small number of pores) on one day and on three days no prominences were found. Faculæ were never absent.

The months which were richest in the various phenomena

TABLE I. (*Continued.*)

Day of month	July					August					September				
	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences
1	9	7	51	8	4	5	9	27	11	8	4	5	22	13	3
2	8	5	38	8	9	8	16	58	..	9	3	6	15	7	5
3	10	7	45	..	7	8	11	83	7	5	7	7	31	13	14
4	8	9	61	10	7	7	13	69	9	2	4	3	24	10	16
5	7	13	30	10	8	5	7	85	7	8	5	6	28	13	6
6	10	17	62	..	6	5	6	56	..	5	8	7	39	14	4
7	9	17	77	14	3	7	9	58	..	3	9	10	50	13	6
8	8	15	99	9	..	7	10	92	..	3	11	11	56	10	3
9	9	15	85	8	..	6	11	36	7	0	11	11	68	11	2
10	11	12	97	9	2	4	11	35	..	..	10	13	52	..	6
11	14	12	85	8	2	5	12	47	6	3	11	12	92	13	4
12	12	17	103	7	4	4	8	27	4	5	11	13	98	11	2
13	12	20	57	10	7	5	10	14	..	8	11	11	109	12	2
14	10	20	53	..	3	5	8	16	..	11	8	11	36	..	2
15	10	17	83	9	..	.	..	..	..	6	8	14	77	12	6
16	10	23	90	11	6	.	..	..	..	6	8	14	54	..	..
17	8	15	78	..	7	9	15	49	8	4	6	8	62	14	6
18	7	19	62	9	3	7	13	25	..	3	5	6	28	11	2
19	6	16	84	11	6	7	10	38	..	6	4	5	14	13	4
20	6	12	54	8	4	8	8	54	..	10	4	4	16	8	4
21	7	14	37	..	4	8	11	33	..	10	5	4	13	..	5
22	8	12	42	11	4	7	6	35	5	6	5	5	15	17	2
23	10	15	35	9	7	6	5	18	8	2	6	5	6	11	3
24	10	10	58	10	7	2	0	6	11	5	7	5	15	13	5
25	7	8	35	..	4	2	1	2	9	0	6	4	18	..	2
26	6	8	37	15	12	4	2	8	13	2	7	3	13	10	2
27	8	7	27	13	10	3	4	16	9	5	4	3	6	9	2
28	6	7	10	14	10	5	5	20	14	6	4	6	6	..	..
29	7	7	13	9	10	4	4	22	11	2	5	6	19	11	6
30	6	8	13	10	10	4	5	39	19	2	5	8	30	12	6
31	5	8	27	13	10	4	5	37	14	2	..	..	..	..	..

TABLE I. (*Continued.*)

Day of month	October					November					December				
	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences	Groups of spots and pores	Spots	Pores	Faculæ	Prominences
1	4	9	25	11	.	5	5	20	..	.	.	..	..	..	.
2	.	..	..	..	.	5	5	26	12	5	.	..	..	..	.
3	7	15	38	..	.	4	5	10	..	3	.	..	..	..	.
4	6	16	46	9	3	5	8	14	6	3	8	23	56	..	3
5	5	15	27	..	.	7	5	48	12	3	8	23	109	14	3
6	.	..	..	..	.	8	9	45	..	3	7	17	64	..	.
7	6	22	61	..	3	5	12	47	11	3	.	..	..	..	.
8	6	26	104	..	5	7	11	45	13	7	7	13	59	14	7
9	7	25	49	..	1?	.	..	..	..	.	6	9	37	13	6
10	7	26	117	..	9	.	..	..	..	.	7	6	53	10	3
11	7	19	76	..	3	.	..	..	..	.	4	9	45	12	5
12	6	20	70	..	.	7	10	67	7	2	.	..	..	..	.
13	9	20	35	..	9	7	7	38	..	3	2	6	5	..	.
14	7	12	29	..	3	6	9	31	9	5	3	6	13	9	2
15	7	10	40	6	3	.	..	..	..	.	1	3?	0?	..	.
16	3	7	16	10	1	5	7	15	9	3	2	10?	1?	..	5
17	3	3	5	10	2	4	5	31	..	.	3	7	27	12	3
18	5	1	12	..	.	6	6	26	10	3	3	17?	10?	..	.
19	6	4	14	..	.	6	6	17	..	2	3	14	42	9	2
20	5	5	29	8	4	6	5	17	..	.	4	9	42	..	.
21	6	6	32	..	.	.	..	..	..	.	4	11	64	5?	.
22	7	8	43	..	.	6	9	33	11	3	.	..	..	..	.
23	6	9	34	11	2	5	8	13	..	.	5	12	39	..	7
24	5	4	46	..	.	6	13	32	..	8	5	11	28	..	4
25	7	5	40	..	.	5	10	30	..	4	7	9	14	..	.
26	6	4	34	9	7	3	10	32	6	4	7	9	24	..	2
27	5	4	36	11	7	7	13	107	7	3	.	..	..	..	.
28	6	7	18	12	3	6	6	30	13	1	.	..	..	..	.
29	5	6	16	..	1	7	6	27	13	.	.	..	..	..	.
30	5	8	19	..	3	6	8	31	..	.	5	6	11	..	4
31	.	..	..	..	.	.	..	..	..	.	8	9	15	11	.

were May for spots and pores,[1] July for groups of spots and pores and for prominences, and September for faculæ.

The quarterly mean frequency shows a regular decrease after the first quarter for the groups of spots and pores, and after the second quarter for the pores. It is irregular for all the other phenomena.

In comparing the results obtained for the prominences and

[1] Pores are distinguished from spots by the fact that their area is less than $\frac{1}{100000}$ of the solar disk.

faculæ a discordance is seen in the different monthly means, but these irregularities partly disappear in the quarterly means, where the two phenomena exhibit the same inflections in the same quarters. If we consider their distribution in the two hemispheres we find, as was the case in 1893, that the prominences have been more numerous in the southern than in the northern hemisphere. The faculæ have shown the same tendency to greater frequency in the southern hemisphere, except in December. The difference has been less marked than for the prominences, but in the quarterly means the southern hemisphere invariably preponderates over the northern.

From a consideration of the distribution of the phenomena in 10° zones of latitude we find:

1. For the faculæ, a marked maximum between 10° and 20°, at nearly the same distance from the equator in both hemispheres; also a secondary maximum in the southern hemisphere

TABLE II.

	Heliographic Latitude	Faculæ					Prominences				
		First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Year	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Year
North	80° to 90°	3	4	4	9	20	0	7	7	0	14
	70 " 80	4	3	13	10	30	0	3	6	0	9
	60 " 70	3	2	16	5	26	3	5	15	2	25
	50 " 60	10	8	25	12	55	2	1	5	4	12
	40 " 50	12	10	26	13	61	3	12	33	10	58
	30 " 40	18	15	47	13	93	9	16	30	13	68
	20 " 30	34	27	44	32	137	23	28	36	23	110
	10 " 20	42	29	72	47	190	25	16	29	21	91
	0 " 10	17	16	66	27	126	16	16	36	10	78
South	0° to 10°	34	22	37	18	111	9	14	34	18	75
	10 " 20	47	31	72	39	189	15	16	48	14	93
	20 " 30	30	35	76	25	166	18	26	38	24	106
	30 " 40	14	13	46	27	100	24	16	34	27	101
	40 " 50	20	13	29	5	67	7	8	12	11	38
	50 " 60	17	19	30	10	76	2	1	1	4	8
	60 " 70	9	20	43	20	92	49	20	2	0	71
	70 " 80	15	3	41	19	78	41	45	52	2	140
	80 " 90	11	5	19	14	49	8	15	35	10	68

TABLE III.

1894	Mean Frequency								
				Of Prominences			Of Faculæ		
	Of groups of spots and pores	Of spots	Of pores	In northern hemisphere	In southern hemisphere	In both hemispheres	In northern hemisphere	In southern hemisphere	In both hemispheres
January	8.93	11.26	42.85	1.94	3.33	5.28	3.94	4.81	8.75
February	7.90	10.33	47.10	1.69	3.75	5.44	3.55	5.55	9.09
March	5.37	6.33	24.85	1.27	3.53	4.80	3.42	4.92	8.33
April	5.62	11.38	35.43	1.19	3.06	4.25	2.87	4.71	7.57
May	7.19	14.69	57.12	1.95	2.24	4.20	3.70	5.60	9.30
June	8.48	13.80	53.64	1.83	2.71	4.54	3.56	4.50	8.06
July	8.52	12.65	55.74	2.93	3.36	6.29	4.56	5.56	10.12
August	5.55	8.10	38.10	2.10	2.80	4.90	4.22	5.33	9.56
September	6.71	7.53	37.07	1.86	2.79	4.64	5.13	6.58	11.71
October	5.86	11.29	39.68	1.44	2.39	3.83	4.70	5.00	9.70
November	5.76	7.92	33.28	1.89	1.68	3.58	4.64	5.29	9.93
December	4.95	10.86	34.45	1.50	2.50	4.00	5.60	5.30	10.90
First Quarter	7.36	9.22	37.56	1.65	3.53	5.18	3.67	5.05	8.72
Second Quarter	7.18	13.42	49.58	1.70	2.64	4.34	3.45	4.88	8.53
Third Quarter	6.97	9.48	43.83	2.29	2.98	5.27	4.67	5.87	10.54
Fourth Quarter	5.56	10.04	36.00	1.63	2.16	3.78	4.94	5.21	10.15
Year	6.77	10.46	41.79	1.88	2.83	4.72	4.27	5.36	9.63

between 60° and 70° and a marked minimum in the polar regions.

2. For the prominences, a marked secondary maximum in both hemispheres between 20° and 30°. The absolute maximum of the year, however, is in the southern hemisphere between 70° and 80°, while the absolute minimum is in the same hemisphere, between 50° and 60°. Another rather marked secondary minimum occurs in the northern hemisphere between 70° and 80°.

From these observations we may conclude that in the case of the prominences the secondary maxima of 1893 have moved toward the equator in both hemispheres, while the absolute maximum has moved nearly 10° toward the south pole, with an abundant outburst in the zone between 80° and 90°, where little was seen in 1893. There is also to be remarked the complete absence of prominences during the first and third quarters of

1894 in the zone comprised between 70° and 90° in the northern hemisphere. As this was not true of the faculæ it is evident that the phenomena of prominences and faculæ are not always in complete accord.

In general, all the phenomena, spots, faculæ and prominences have continued to decrease since 1893, the year of the last maximum of solar activity.

For the spots the year 1894 has been quite characteristic on account of a marked secondary maximum which occurred in the second quarter, following the absolute maximum in 1893 of the eleven-year period. In this we see a repetition of the phenomenon of the preceding maximum, when the absolute maximum of 1884 was followed by a very marked secondary maximum in 1885.

CATANIA, SICILY,
May 12, 1895.

A SPECTROGRAPHIC DETERMINATION OF VELOCITIES IN THE SYSTEM OF SATURN.

By W. W. CAMPBELL.

HAVING just begun to use the new Mills spectrograph, I have had the opportunty of making its first work a confirmation of the beautiful results obtained by Professor Keeler in the Saturnian system. The spectrograph will be fully described in a subsequent paper, and it is necessary here to state only that it has been designed solely for determining the velocities of stars in the line of sight, using the $H\gamma$ region of the spectrum. The collimator is $723^{mm}.5$ long, the camera about 416^{mm} (not yet accurately determined), and the dispersive train consists of three very dense flint 60° prisms.

A brief description of the guiding apparatus may not be without interest. The method used by Professor Vogel, Professor Keeler and others is inapplicable for photographing in the $H\gamma$ region when the telescope is large, on account of the chromatic aberration of the visual objective. To be certain that the $H\gamma$ image of a star falls centrally on the slit, it is necessary to guide by means of $H\gamma$ light which has already passed through the slit. The Mills spectrograph is so arranged that the light reflected from the first prism surface passes through a 30° prism and thence into the guiding telescope. The observer guides by means of the auxiliary spectrum thus formed. The eyepiece is focused on the $H\gamma$ region, and a wire is so situated that it covers all of the guiding spectrum *except* the $H\gamma$ region. Whenever the observer sees light in the eyepiece, the $H\gamma$ image of the star is properly placed on the slit, and *vice versa;* the slit-length being made equal to the desired spectrum-width. In the case of Saturn very accurate guiding in right ascension was required; and as the $H\gamma$ region of the guiding spectrum was rather faint, it was only necessary to push the eyepiece slightly inwards to bring the yellow region into focus. The planet's spectrum was

kept bisected by the occulting wire of the eyepiece, and in this way very accurate guiding in right ascension was secured.

Four spectrograms were obtained with the slit passing east and west through the center of the Saturnian system. They are:

Plate	Date	Slit-width
1	1895, May 10^d 11^h 0^m to 12^h 35^m	$0^{mm}.04$
2	" 14 10 45 " 12 15	0 .04
3	" 15 10 10 " 12 5	0 .04
4	" 16 9 30 " 11 30	0 .03

The lunar spectrum was photographed on each plate, on both sides of, and as close as possible to, the spectrum of the planet system. The $H\gamma$ hydrogen line was photographed on the first and third plates. All the spectrograms are suitable for measurement. However, the guiding telescope was accidentally displaced for Plate 3, so that the lunar and hydrogen spectra are not symmetrically placed with reference to the planet's spectrum, and for that reason Plate 3 has not been measured.

My photographs confirm the results obtained by Professor Keeler as to the velocity of rotation of the planet, as to the velocity of rotation of the center of the ring system, and as to the fact that the inner edge of the ring system rotates more rapidly than the outer edge. Moreover, the scale of the photographs is sufficiently large to enable us to determine the *excess* of velocity of the inner edge over that of the outer edge.

(*a*) The velocity of the east and west points of the planet's equator, due to diurnal rotation, was found by measuring the inclination ϕ of the planet's lines to the lunar lines, and reducing by the formula[1]

$$V' = \frac{\rho DL \tan \phi}{2\lambda \cos \beta}.$$

The direction of the lunar lines, *i. e.*, the zero reading of the circle, was obtained from one or more readings on each of ten lunar lines. The directions of the planet's lines were obtained

[1] I have used Professor Keeler's notation and equations. See this JOURNAL, 1, 416–427.

from three readings on each of ten lines. The values of ρ on the three dates were:

May 10	$\rho = 0^{mm}.4553$
" 14	$\rho = 0\ .4542$
" 16	$\rho = 0\ .4537$

The velocity computed from Professor Hall's period of rotation for the planet is $10^{km}.29$ per second.

PLATE 1.

λ	D	ϕ	Velocity of limb	$C-O$
Tenth-meters	Tenth-meters		Kilometers	Kilometers
4308.0	11.80	2° 43′	9.27	+1.02
4315.2	11.88	2 32	8.71	+1.58
4325.9	12.12	3 1	10.54	−0.25
4340.6	12.40	2 39	9.45	+0.84
4352.0	12.70	2 20	8.69	+1.60
4358.7	12.84	2 47	10.24	+0.05
4367.8	13.02	2 28	9.20	+1.09
4369.9	13.05	2 32	9.45	+0.84
4371.3	13.08	2 44	10.21	+0.08
4404.9	13.76	2 37	10.21	+0.08
			9.60	+0.69

PLATE 2.

λ	D	ϕ	Velocity of limb	$C-O$
Tenth-meters	Tenth-meters		Kilometers	Kilometers
4315.2	11.88	2° 53′	9.89	+0.40
4318.8	11.94	2 43	9.37	+0.92
4321.0	11.99	3 15	11.25	−0.96
4325.9	12.12	3 1	10.51	−0.22
4340.6	12.40	2 35	9.19	+1.10
4352.0	12.70	3 0	10.89	−0.60
4359.8	12.86	3 0	11.03	−0.74
4367.8	13.02	2 49	10.48	−0.19
4371.3	13.08	2 44	10.19	+0.10
4404.9	13.76	2 35	9.82	+0.47
			10.26	+0.03

PLATE 4.

λ	D	ϕ	Velocity of limb	$C-O$
Tenth-meters	Tenth-meters		Kilometers	Kilometers
4315.2	11.88	2° 56′	10.05	+0.24
4318.8	11.94	2 43	9.36	+0.93
4321.0	11.99	2 41	9.27	+1.02
4325.9	12.12	2 45	9.59	+0.70
4340.6	12.40	2 29	8.85	+1.44
4352.0	12.70	2 11	7.91	+2.38
4359.8	12.86	3 2	11.14	−0.85
4367.8	13.02	2 36	9.66	+0.63
4404.9	13.76	2 29	9.65	+0.64
4415.3	13.94	2 20	9.15	+1.14
			9.46	+0.83

The velocity due to the planet's rotation is, from the three plates,

$$\tfrac{1}{3}\,(9.60 + 10.26 + 9.46) = 9^{km}.77,$$

differing $0^{km}.52$ from the computed value.

(*b*) The velocity of rotation of the middle of the ring system was found by measuring the relative linear displacement δ of corresponding lines in the opposite ansæ, and reducing them by the formula

$$V'' = \frac{DL\delta}{4\lambda \cos\beta}.$$

The displacement δ was measured directly by first bringing the lines in the opposite lunar spectra into parallelism with the

PLATE 1.

λ	D	δ	Velocity of middle of ring	$C-O$
Tenth-meters	Tenth-meters	Millimeters	Kilometers	Kilometers
4308.0	11.80	0.0842	18.06	+0.72
4315.2	11.88	0.0758	16.43	+2.35
4321.0	11.99	0.0782	17.06	+1.72
4340.6	12.40	0.0760	17.04	+1.74
4352.0	12.70	0.0702	16.08	+2.70
4358.7	12.84	0.0818	18.97	−0.19
4359.8	12.86	0.0780	18.09	+0.69
4367.8	13.02	0.0760	17 82	+0.96
4369.9	13.05	0.0675	15.87	+2.91
4371.3	13.08	0.0780	18.33	+0.45
			17.38	+1.40

PLATE 2.

λ	*D*	δ	Velocity of middle of ring	*C—O*
Tenth-meters	Tenth-meters	Millimeters	Kilometers	Kilometers
4315.2	11.88	0.0832	18.05	+0.73
4318.8	11.94	0.0755	16.41	+2.37
4321.0	11.99	0.0770	16.79	+1.99
4340.6	12.40	0.0778	17.43	+1.35
4352.0	12.70	0.0772	17.68	+1.10
4352.9	12.72	0.0785	18.01	−0.77
4359.8	12.86	0.0785	18.20	+0.58
4367.8	13.02	0.0740	17.35	+1.43
4371.3	13.08	0.0675	15.86	+2.92
4415.3	13.94	0.0728	18.01	+0.77
			17.38	+1.40

PLATE 4.

λ	*D*	δ	Velocity of middle of ring	*C—O*
Tenth-meters	Tenth-meters	Millimeters	Kilometers	Kilometers
4315.2	11.88	0.0805	17.47	+1.31
4318.8	11.94	0.0772	16.80	+1.98
4321.0	11.99	0.0770	16.79	+1.99
4325.9	12.12	0.0828	16.65	+2.13
4337.2	12.36	0.0828	16.11	+2.67
4352.0	12.70	0.0778	17.78	+1.00
4352.9	12.72	0.0788	18.07	+0.71
4358.7	12.84	0.0818	18.91	−0.13
4359.8	12.86	0.0762	17.68	+1.10
4369.9	13.05	0.0732	17.16	+1.62
			17.34	+1.44

micrometer wire and making three micrometer readings on each of ten corresponding lines in the opposite ansæ, and the same number of readings on the same lines in the adjacent lunar spectra. In that manner the prismatic curvature of the lines was satisfactorily eliminated. The results obtained from three plates are given below. The computed velocity of a supposed satellite, situated at the middle of the ring system, is $18^{km}.78$ per second.

The velocity of the middle of the ring system is, from the three plates, $\frac{1}{3}(17.38+17.38+17.34)=17^{km}.37$;

differing $1^{km}.41$ from the computed value.

(*c*) All the lines in the photographs of the spectra of the rings show that the inner edge revolves more rapidly than the outer edge, since they all incline in the direction opposite that of the lines in the planet's spectrum. The excess of the velocity of the inner edge over that of the outer edge was found, by measuring the inclination ϕ' of the lines in the ring spectrum, to the lines in the lunar spectrum, and reducing by the formula

$$V'' = \frac{\rho' DL \tan \phi'}{2\lambda \cos \beta},$$

in which ρ' is the width of the ring in millimeters. One measure of ϕ' was made on each of ten corresponding lines in the spectra of the two ansæ. By taking the mean of the measured inclinations of the same line in both ansæ, the prismatic curvature of the lines was eliminated. The values of ρ' for the three dates were

May 10, $\rho' = 0^{mm}.3410$
14, $\rho' = 0\ .3402$
16, $\rho' = 0\ .3398$

The computed excess of velocity of a supposed satellite at the inner edge of the ring system over that of a supposed satellite at the outer edge is $3^{km}.87$.

PLATE I.

λ	D	ϕ	Excess for inner edge	$C-O$
Tenth meters	Tenth-meters		Kilometers	Kilometers
4340.6	12.40	1° 8′	3.03	+0.84
4359.8	12.86	1 30	4.14	−0.27
4367.8	13.02	1 29	4.14	−0.27
4369.9	13.05	1 7	3.12	+0.75
4371.3	13.08	0 59	2.75	+1.12
4395.3	13.56	0 50	3.03	+0.84
4404.9	13.76	1 9	3.34	+0.53
4415.3	13.94	0 49	2.41	+1.46
4425.6	14.12	1 12	2.84	+1.03
4427.5	14.16	0 56	2.79	+1.08
			3.16	+0.71

PLATE 2.

λ	*D*	φ	Excess for inner edge	*C—O*
Tenth-meters	Tenth-meters		Kilometers	Kilometers
4315.2	11.88	0° 49′	2.10	+1.77
4318.8	11.94	1 8	2.93	+0.94
4321.0	11.99	1 8	2.94	+0.93
4325.9	12.12	1 1	2.65	+1.22
4352.0	12.70	1 20	3.62	+1.25
4369.9	13.05	1 20	3.72	+0.15
4395.3	13.56	0 57	2.73	+0.14
4404.9	13.76	0 56	2.72	+1.15
4415.3	13.94	1 10	3.43	+0.44
4427.5	14.16	1 15	3.73	+0.14
			3.06	+0.81

PLATE 4.

λ	*D*	φ	Excess for inner edge	*C—O*
Tenth-meters	Tenth-meters		Kilometers	Kilometers
4308.0	11.80	1° 18′	3.31	+0.56
4315.2	11.88	0 56	2.39	+1.48
4318.8	11.94	1 11	3.05	+0.82
4321.0	11.99	1 11	3.06	+0.81
4340.6	12.40	1 15	3.33	+0.54
4352.0	12.70	1 26	4.07	−0.20
4358.7	12.84	1 17	3.52	+0.35
4359.8	12.86	1 13	3.34	+0.53
4367.8	13.02	1 3	2.92	+0.95
4369.9	13.05	0 58	2.69	+1.18
			3.17	+0.70

The excess of velocity for the inner edge is, from the three plates,

$$\tfrac{1}{3}\,(3.16+3.06+3.17)=3^{km}.13,$$

differing $0^{km}.74$ from the computed value. The probable error indicated by the thirty individual results is very small, showing that the direction of the lines in the spectra of the ansæ is well defined and easily measurable.

(*d*) During the exposure on Plate 1, a small portion of the center of the slit was left covered; and at the close of the

exposure the hydrogen spectrum was photographed upon the unoccupied center of the plate corresponding to the previously covered central portion of the slit. The artificial $H\gamma$ line thus fell between the two halves of the $H\gamma$ line in Saturn's spectrum. The center of the $H\gamma$ line in the planet's spectrum was displaced toward the red 0.12 tenth-meter, corresponding to a velocity of recession of $8^{km}.3$. At the time of observation Saturn was receding from the Sun at the rate of $0^{km}.4$ per second, by which amount the observed recession from the Earth must be decreased. The observed recession thus reduces to $7^{km}.9$. The velocity of recession computed from the data of the *Nautical Almanac* is $8^{km}.7$. The error of the observation is therefore $0^{km}.8$.

We may say that these observations agree with those made by Professor Keeler in confirming the accepted period of rotation of the planet and the meteoric theory of the constitution of the rings.

The thirty separate results for the velocity of rotation of the planet, for the velocity of rotation of the middle point of the ring system, and for the excess of velocity of the inner edge of the ring system over that of the outer, agree well with each other, and therefore give small probable errors. However, the results are systematically smaller than theory requires. I attribute the discrepancy to the probability that the slit did not remain upon the major axis of the system of Saturn throughout the exposures. If the method of guiding depends upon light which has already passed through the slit, it is impossible to say from the guiding image whether the slit is directed upon the major axis of the system, or is slightly to one side of the major axis. We may be sure, in long exposures, that the slit would lie ouside of the axis much of the time. The relative velocities obtained from the photographs would refer to portions of the system some distance from the axis, where the relative velocities in the line of sight are smaller than those computed for points lying on the axis. Experiments recently made with the guiding apparatus have convinced me that the image of Saturn could have been displaced

sidewise from the slit sufficiently to account for much of the discrepancy observed, without suspecting, from the guiding image, that the slit did not coincide with the major axis of the system.

The methods of guiding employed by Professor Keeler and myself are thoroughly satisfactory for keeping the image fixed in the direction of the length of the slit; but to be certain that the major axis of the Saturnian system remains constantly upon the slit, it is essential that we see all, or a large part, of the image of the system. This can only be done by guiding in front of the slit. Dr. Huggins' method of guiding by means of the image reflected from a polished slit-plate would seem to be satisfactory. A movable diagonal eyepiece that could occasionally be run in immediately in front of the slit, with a cross-wire adjusted to coincide with the slit, would be satisfactory for keeping the slit upon the major axis of the image. If either of these methods had been employed, I have little doubt that the systematic difference between the observed and computed velocities would not exist, and that the very small probable errors would be still smaller.

MT. HAMILTON,
May 27, 1895.

ON THE EXISTENCE OF A TWILIGHT ARC UPON THE PLANET MARS.

By PERCIVAL LOWELL.

DURING last autumn Mr. Douglass made at this Observatory 275 micrometric measures of the diameters of Mars. After reducing and discussing these, I find that they give as the most probable value for the equatorial diameter of the planet at distance unity: $9''.40 \pm .007$; for the polar one: $9''.35 \pm .005$; and for the polar flattening $\frac{1}{190}$ of the equatorial diameter. But besides such direct outcome of the measurements, there emerges a by-product as interesting as it is unexpected. For their discussion discloses apparently the existence of a twilight arc upon the planet, sufficiently pronounced to be visible from the Earth and actually to have been measured, unconsciously, by Mr. Douglass.

That the fact should be brought to light in this manner, as a silver lining to a mere cloud of figures, is, I think, a point of some curiosity. That the planet had an atmosphere we had what amounted to proof positive before, but that its presence should thus be revealed by measures made for another purpose, and only after these same measures had been carefully discussed, was not so instantly to be looked for. To have made measures with this end in view would not have suggested itself as possible. Yet, as will be seen, the quantities upon which the evidence rests are so large as to be quite beyond the probable errors of observation, larger even than those that disclose the polar flattening.

Following are three tables giving the measures in detail and the means and other values deduced from them.

The first measures were made on the 20th of September and the last on the 21st of November, 1894. From the 12th of October they were taken nearly every night. They were all made by Mr. Douglass. Here at the outset it may be well to point out that whether the results of many observers are to be preferred to one is, omitting personalities, a question entirely of

what it is that is to be determined. If the determination is one of absolute quantities, the more observers the better, provided they be good, but if on the other hand the determination is one of relative magnitudes, one observer is better than many, as his personal equation eliminates itself, whereas two such equations can by no possibility, except the merest coincidence, eliminate each other. Now in the present case, while the determination of the planet's size and even to some extent of its polar flattening are matters of absolute quantity, the evidence of a twilight is one which rests on measures of relative results. The former, therefore, are subject to any systematic errors there may be; the latter essentially free of them. In consequence, in this case the by-product is actually more trustworthy than the main results themselves.

TABLE I.

POLAR DIAMETERS.

Time	No. of Measures	Wt.	Uncor. Meas.	Cor. for Refrac.	Cor. for Irrad. on Limb	Cor. for Irrad. on Term.	Cor. for Phase	Reduced to distance unity	
Sept. 20 14^h 00^m	5	4	20".59	20".59	20".45	20".38	20".54	9".54	E. S.
" 23 14 35	5	5	20 .85	20 .86	20 .76	20 .71	20 .85	9 .51	E. D.
Oct. 5 14 36	7	4	21 .77	21 .78	21 .68	21 .62	21 .68	9 .42	
" 12 13 45	5	5	21 .95	21 .95	21 .85	21 .79	21 .81	9 .40	
" 15 13 42	6	4	21 .84	21 .84	21 .74	21 .67	21 .68	9 .36	E. R. A.
" 17 15	4	4	21 .78	21 .78	21 .68	21 .60	21 .61	9 .37	E. S.
" 19 15 5	5	2	21 .92	21 .92	21 .82	21 .73	21 .73	9 .46	E. S.
" 20 13 57	5	5	21 .69	21 .69	21 .59	21 .50	21 .50	9 .41	E. S.
" 21 13 42	5	5	21 .69	21 .70	21 .60	21 .51	21 .51	9 .42	E. D.
" 21 14	5	4	21 .61	21 .61	21 .51	21 .42	21 .42	9 .39	E. S.
" 23 13 40	5	4	21 .28	21 .28	21 .18	21 .08	21 .08	9 .31	E. S.
" 24 12 15	5	3	21 .17	21 .17	21 .07	20 .97	20 .97	9 .30	E. S.
" 24 12 33	6	3	21 .08	21 .09	20 .99	20 .89	20 .89	9 .27	E. D.
" 29 13 16	5	3	20 .94	20 .94	20 .84	20 .75	20 .75	9 .46	E. S.
" 30 14 50	7	3	20 .78	20 .78	20 .68	20 .59	20 .59	9 .46	E. S.
Nov. 2 13 34	5	6	20 .15	20 .15	20 .05	19 .97	19 .97	9 .36	E. S.
" 4 12 40	5	4	19 .85	19 .85	19 .75	19 .67	19 .68	9 .37	E. S.
" 5 13 10	5	5	19 .61	19 .61	19 .51	19 .43	19 .44	9 .34	E. S.
" 5 14 38	5	3	19 .54	19 .54	19 .44	19 .36	19 .37	9 .30	E. S.
" 6 12 45	5	7	19 .67	19 .67	19 .57	19 .49	19 .50	9 .44	E. S.
" 9 13 35	5	7	19 .23	19 .23	19 .13	19 .05	19 .07	9 .49	E. S.
" 14 14 35	5	6	18 .00	18 .00	17 .90	17 .83	17 .86	9 .33	E. S.
" 15 13 53	5	5	18 .02	18 .02	17 .92	17 .85	17 .88	9 .44	E. S.
" 19 12 45	5	3	17 .20	17 .20	17 .10	17 .03	17 .07	9 .39	E. S.
" 20 11 50	5	2	17 .15	17 .15	17 .05	16 .99	17 .03	9 .46	E. S.
" 21 11 45	5	7	16 .86	16 .86	16 .76	16 .70	16 .74	9 .40	E. S.

TABLE II.

EQUATORIAL DIAMETERS.

Time			No. of Measures	Wt.	Uncor. Meas.	Cor. for Refrac.	Cor. for Irrad. on Limb	Cor. for Irrad. on Term.	Cor. for Phase	Reduced to distance unity	
Sept. 20	14h	15m	5	5	19".69	19".70	19".56	19".53	20".39	9".47	E. S.
" 23	14	12	5	6	20 .11	20 .11	20 .01	19 .99	20 .71	9 .45	E. D.
Oct. 5	14	15	7	4	21 .83	21 .83	21 .73	21 .69	20 .94	9 .53	
" 12	13	15	5	5	22 .15	22 .15	22 .05	21 .99	22 .06	9 .51	
" 15	14	2	5	3	21 .96	21 .96	21 .86	21 .78	21 .80	9 .42	E. S.
" 17	14	42	5	4	21 .99	21 .99	21 .89	21 .79	21 .79	9 .44	E. S.
" 19	14	48	5	3	22 .00	22 .01	21 .91	21 .81	21 .81	9 .50	E. S.
" 20	14	11	5	6	21 .80	21 .81	21 .71	21 .61	21 .61	9 .44	E. S. ?
" 21	14	25	6	4	21 .74	21 .75	21 .65	21 .56	21 .56	9 .45	E. D.
" 21	14	45	5	5	21 .57	21 .58	21 .48	21 .39	21 .39	9 .37	E. S.
" 23	14	15	7	3	21 .45	21 .46	21 .36	21 .28	21 .30	9 .40	E. S.
" 24	11	50	6	3	21 .38	21 .38	21 .28	21 .21	21 .24	9 .42	E. S.
" 24	12	50	5	5	21 .32	21 .33	21 .23	21 .16	21 .19	9 .40	E. D.
" 29	13	3	5	3	20 .91	20 .92	20 .82	20 .77	20 .88	9 .52	E. D.
" 30	15		5	2	20 .54	20 .55	20 .45	20 .40	20 .54	9 .43	E. D.
Nov. 2	14	12	5	6	20 .03	20 .04	19 .94	19 .89	20 .10	9 .42	E. D.
" 4	13	10	5	4	19 .87	19 .88	19 .78	19 .74	20 .01	9 .53	E. D.
" 5	13	36	5	4	19 .49	19 .50	19 .40	19 .36	19 .66	9 .44	E. D.
" 5	14	15	5	3	19 .46	19 .48	19 .38	19 .34	19 .64	9 .43	E. D.
" 6	13	20	6	8	19 .59	19 .60	19 .50	19 .46	19 .79	9 .58	E. D.
" 9	13	53	5	7	19 .04	19 .06	18 .96	18 .92	19 .34	9 .62	E. D.
" 14	14	18	7	6	17 .89	17 .92	17 .82	17 .79	18 .36	9 .58	E. D.
" 15	13	36	7	6	17 .68	17 .70	17 .60	17 .57	18 .17	9 .58	E. D.
" 19	13		5	5	16 .76	16 .78	16 .68	16 .66	17 .36	9 .55	E. D.
" 20	12	20	5	6	16 .65	16 .67	16 .57	16 .55	17 .28	9 .60	E. D.
" 21	11	58	4	1	16 .34	16 .35	16 .25	16 .23	16 .98	9 .53	E. D.

TABLE III.

MEANS.—*Polar Diameters.*

		Measures Cor. for Refrac., Irrad., and Phase	Cor. for Inclination	Further Cor. for Twilight Band
Oct. 15th to 23d inclusive	9".385	9".379	9".356	0.011
Oct. 12th to 30th inclusive	9 .384	9 .378	9 .354	0.011
Nov. 2d to 21st inclusive	9 .397	9 .390	9 .353	0.012

Equatorial Diameters.

Oct. 15th to 23d inclusive	9".420	No cor.	9".404	0.010
Oct. 12th to 30th inclusive	9 .440	No cor.	9 .396	0.010
Nov. 2d to 21st inclusive	9 .545	No cor.	9 .402	0.012

RESULTING VALUES.

Equatorial Diameter	9".40 ± .007
Polar Diameter	9 .35 ± .007
Polar Flattening	$\frac{1}{190}$
Visible Twilight Arc	10°

To eliminate systematic errors as much as possible a circular disk of determinate size was made and placed upon the summit of one of the San Francisco peaks, facing the Observatory. The size of the disk was such as to subtend at that distance an angle very nearly equal to the planet's disk. Measurements were then made by Mr. Douglass of the horizontal and vertical diameter of this disk which when corrected for refraction give accurate values for any interesting defects in the observer.

Similar care was taken in the matter of the Martian measures themselves. After adjusting the longitudinal thread of the micrometer according to Marth's ephemeris, parallel or perpendicular, as the case might be, to the planet's polar disk, Mr. Douglass placed his head so that the line joining his eyes was kept parallel to this thread or to the fixed transverse thread at right angles to it, during any one set of observations, and the position was then recorded. Such record appears in column 10 of the table here given: E. S. standing for "eyes parallel to single thread," that is the longitudinal thread of the micrometer, and E. D. "eyes parallel to double (*i. e.*, transverse) threads." As measures were taken in both positions for each diameter at various times, the effect of such position upon the result is deducible at once from the measures themselves.

Of the 275 measures, 140 were of the equatorial diameter and 135 of the polar one. Usually five measures were taken in a set, the mean of each set when reduced to angular value

appearing in column 4 of the table. Columns 5, 6, 7 and 8 give the values when corrected respectively for refraction and aberration, irradiation and phase.

The correction for refraction is the differential effect of refraction upon the planet's opposite limbs at the extremities of the particular diameters measured. It depends both upon the altitude of the planet at the time of observation, and upon the inclination, at that moment, of the particular diameter to the vertical. In many cases it was so small as not to make itself evident in the column.

The correction for aberration, similarly a differential effect, was utterly insignificant in all cases.

Third came the correction for irradiation. This is the only correction into which some fundamental uncertainty enters; but as will be seen it in no case affects the fundamental result, the twilight arc. Two different tests made under different conditions and in each case both upon Professor W. H. Pickering and myself, give limiting measures, the one limit being greater, the other less than would occur with Mars; and as in both cases the observers substantially agreed, the results may be accepted provisionally as having some impersonal value. The first test was made upon a railroad switchhead, a white circular disk with a smaller black circle painted upon it. The size of the circles was unknown to the observers. Their estimates were:

(W. H. P.)	1	(white rim)	1.3	(diam. black circle)
(P. L. two sets, mean)	1	" "	1.265	" "

The disks and their distance were then measured, and gave:

For the diameter black circle, 202 mm
radius white rim, 126 mm
ratio, $\frac{9}{16}$
distance from eye, 57 yds
$\therefore$ 1 mm = 3".9

For amount of irradiation in seconds of arc, x, assume amount of irradiation of white rim against the general background of earth of a brown color to have been $\frac{2}{3}$ that of rim

against the black circle. We have, then, for the first observer, the following equation to determine x:

$$\frac{252^{mm} + \frac{10}{3}x}{202^{mm} - \frac{6}{3}x} = \frac{2}{1.3},$$

from which $x = 9^{mm}.2$ or $36''$;
for the second observer $x = 40''$.

The second test was on the Moon (November 22), when the old Moon was seen in the new Moon's arms. In this case the irradiation proved to be, for both observers, about $157''$.

In the case of Mars, the value for the irradiation probably lies between these two limits. For the contrast between the Martian limb and the sky certainly lies between that of the black circle against the white rim in the first test and that of the Moon's bright limb against the sky. And as the contrast between the old Moon's limb or the dark limb and the sky is very slight, the contrast in the second test is almost equivalent to that of the Moon's bright limb against the sky. From this it would seem that something near a mean between the two is a probable value for the irradiation in the case of Mars. In my own case this would be probably $100''$, but with Mr. Douglass I judge it, from experience, to be less. If we take $86''$, which is as near as we can come, it gives, with the power (860) used in the measures, $0''.1$ exactly to be subtracted from all the measures.

It is to be noted that, with a given illumination and a given eye, the irradiation correction is a personal constant, not depending upon the size of the disk measured and diminishing inversely as the magnification. Dividing, therefore, $86''$ by 860 we get $0''.1$ as the value of the constant in all measures made except those of September 20, when a power of 617 was employed and gave $0''.14$.

Such is the correction for the limb. The correction for the terminator is given by the equation

$$\frac{1}{m}\left(\frac{\sin\alpha}{\sin\alpha + \gamma}\right)^{\frac{1}{\pi}} - \left(\cos\gamma - \cos(\gamma + \alpha)\right)$$

where γ = the phase angle,
α = the angle from the terminator to the point whose irradiation is sought,
m = the ratio of the irradiation at the limb to the radius, and
n = the ratio of the illumination to the irradiation.

Fourth was the correction for phase. Inasmuch as the phase axis and the polar axis did not in general coincide, there entered into its determination, beside the amount of the lacking lune, the angle of inclination of the two axes. So that the amount of defalcation had to be calculated in accordance each night.

Fifth was the correction needed to reduce the diameter, measured for the polar one, to the true polar diameter. The diameter measured perpendicular to this, or the apparent equatorial diameter, though not in fact an equatorial diameter, was always exactly equivalent to one, since its extremities were always each 90° distant from the pole. The other, however, was that diameter of the ellipse made by the plane passing through the polar axis, which was inclined to the polar axis by the angle of tilt and needed to be reduced to that ellipse's minor axis to give the true polar diameter.

Lastly the correction for astigmatism was nil; inasmuch as the value of a micrometer turn and the image itself were increased or diminished in the same proportion.

So soon as the measures had been corrected and reduced to distance unity, the first thing to show was the polar flattening—so large as to be almost unmistakable even before taking the means. Nearly as instantly it was apparent that something had affected the equatorial measures between October and November, the November measures seeming systematically larger than the October ones, the corresponding polar measures on the other hand showing no such increase. Struck by this appearance, and suspecting its cause, instead of taking the mean of all the measures for each diameter I divided them into sets according to their proximity in date to the time of opposition and took the mean of these sets. Opposition recurred on October 20. The measures taken, therefore, between October 15 and October 24

were all made within five days of opposition; those taken on October 12, 29 and 30 from eight to ten days away from it; and those from November 2 to November 21 from thirteen to thirty-two days distant. Taking the first two sets together against the third we have:

Mean 64 meas.	Oct. 12–30	Equat. diam. cor. for refrac., irrad. and phase.....	9".440 ± .010
Mean 59 meas.	Nov. 2–21	Equat. diam. cor. for refrac., irrad. and phase.....	9".545 ± .012
Mean 63 meas.	Oct. 12–30	Polar diam. cor. for refrac., irrad. and phase.....	9".378 ± .011
Mean 55 meas.	Nov. 2–21	Polar diam. cor. for refrac., irrad. and phase.....	9".390 ± .011

The agreement of the two polar means is as striking as the disagreement of the two equatorial ones is noticeable. The two polar values differ by but twelve units in the third place of decimals, a quantity much less than the probable error of either measure. The equatorial values, on the other hand, differ by one hundred and five such units, or by ten times the probable error. The divergence appears yet more systematic if we divide the equatorial diameters into three sets, as above mentioned, and take the mean of each set.

Mean, October	15–24	Equatorial diameter,	9".424
" "	12–29	" "	9".497
" November	2–21	" "	9".545

As these measures had already been corrected for everything, phase included, both the equatorial and the polar ones should have agreed among themselves on the several occasions. The polar did so in a most satisfactory manner; the equatorial did not; now the only point of dissimilarity in the conditions of measurement of the two consisted in the fact of phase.

The polar diameters terminated always, practically speaking, in two bright limbs, as did also those equatorial diameters that were measured between October 15 and October 24. In other cases the equatorial ones were bounded but on one side by a limb, on the other being limited by a terminator. In the polar and

the first equatorial sets the phase angle was, as a rule, less than 5°; in the middle equatorial set it was between 5° and 10°; while in the last it rose from 12° to 25°. Apparently, then, the cause lay somehow included in the question of phase. Now there is a cause dependent on phase which is capable of explaining the observed effect, and seemingly only one. If the planet possessed an atmosphere dense enough, its twilight arc would produce precisely the increase noted, for it would insensibly increase the measures at a distance from opposition, and when these were subsequently corrected for phase, upon the supposition that there was no twilight arc, the result would be an apparent increase in the equatorial diameter.

The effect, therefore, is explicable by the presence of a measurable twilight arc. Nor is there any other factor in the case capable, apparently, of accounting for it, for the data upon which this part of the ephemeris rests are too accurately known to admit of errors of the sort, being such well-determined things as the areocentric angle between the Earth and the Sun, and the relative distances of the two planets from that body. Besides these there is nothing which enters into the calculation but the position of the pole of Mars, and this would have to be some thirty-five Martian degrees in error to explain the discrepancy. Such an error of position is quite inadmissible.

Another point connected with these measurements is worth noting: that in the absence of atmosphere the measures of the equatorial diameter as soon as the phase became marked should have shown a decrease, inasmuch as it would be impossible for an observer to catch the last faintly illuminated portion, whereas, on the contrary, they showed an increase.

To determine the extent of the twilight arc: If we call E the angle measuring the amount of the phase; T = the angle between the radius to the sunset point and the radius prolonged to the point of the atmosphere last illuminated; a = the true equatorial radius reduced to distance unity, and b = the corresponding amount of its apparent excess, we have the following equation to determine T:

$$\frac{1 + \cos E + \sin E \tan T}{1 + \cos E} 2a = 2a + b,$$

whence

$$\tan T = \frac{b + \cos E}{2a \sin E}$$

in which are to be substituted the values of $2a$ and b. But as b is the mean value of the excess of the equatorial diameter from November 2 to November 21 we must take the mean value of $\frac{1 + \cos E}{\sin E}$ between the same limits.

If dE were constant, the mean value would be:

$$\frac{\int_{E_1}^{E_2} \frac{1 + \cos E}{\sin E} dE}{\int_{E_1}^{E_2} dE},$$

where E_1 and E_2 represent the extreme values of E; but as dE is not constant its value, in terms of dt, must be substituted from the elliptic motions. A short cut to the result may, however, be taken by deducing this mean value from the differences, properly reduced, of the values in columns 7 and 8 of Table 2, for the given dates.

By so doing we get:

$T = 5°$, or the twilight arc $= 10°$; since T is half the twilight arc.

This twilight arc introduces a correction into the values of the equatorial diameter, of the polar diameter, of the polar flattening and of the twilight arc itself. Introducing these corrections we get for the final values of all these quantities the following close accordance.

Equatorial Diameter,	Oct. 15–24	9″.402
" "	Nov. 2–21	9 .402
Polar Diameter,	Oct. 12–30	9 .354
" "	Nov. 2–21	9 .353
Polar Flattening, $\frac{1}{100}$		
Twilight Arc, 10°		

We will now consider what seem anomalies, the September observations. In these the equatorial measures come out too small as compared with the late November ones, while the polar ones come out considerably too large. In the case of the equatorial measures the differences may conceivably fall within the errors of observation since there are instances of like variation elsewhere. In the case of the polar measures, however, the discrepancy seems too large to be thus accounted for, being of such size as to make the polar diameter on those dates much larger than the equatorial. On reflection a possible cause suggests itself for such increase. For in September there was still a visible polar cap, excentric to the pole and, as the pole was tilted toward the observer, the rotation of the planet would at times bring it upon the limb where its great brilliancy would produce excessive irradiation and cause the polar diameter to measure too much. Now calculation reveals the fact that at the hours on September 20 and 23 when the measures were made the polar cap was indeed upon that side of the pole farthest from the observer and not very far from its position of maximum irradiation effect. On the other hand on October 5, in whose measure no such increase appears, the ephemeris shows that at the time the measure was made the polar cap was on the hither side of the pole; as it was also on October 12. Here, then, we have what seems a satisfactory explanation of the phenomenon.

On October 13 the polar cap vanished and substantially continued so; so that the subsequent measures were little or not at all affected by it.

From the length of the twilight arc, the density of the atmospheric envelope at the surface of the planet may be calculated, supposing the atmosphere to be similar to our own. For if $x =$ height above the surface and $y =$ the density of the air at that point, we have generally from the property

$$\frac{dy}{dx} = -ay,$$

$$\log y = -ax + b,$$

as the equation to determine y. We should have, therefore, for the Earth the equation:

$$\log y = -a_1 x + b_1,$$

and for Mars the corresponding one:

$$\log y = -a_2 x + b_2.$$

The values of the constants a_1 and b_1 are known from experiment and the value of a_2 is given by the equation

$$\frac{a_1}{a_2} = \frac{g_1}{g_2},$$

where g_1 and g_2 are the forces of gravity at the surface of the two planets respectively, since the densities are proportional to the pressures and these in turn proportional to the forces of gravity.

If the two atmospheres were similar we should have for the heights, x_1 and x_2, at which respectively the reflected light ceased to be capable of detection:

$$y_1 = y_2$$

$$\text{or } \log y_1 = \log y_2,$$

whence

$$-a_1 x_1 + b_1 = -a_2 x_2 + b_2,$$

from which we should get the value of b_2. In the determination the constants would themselves be functions of x, owing to changes in the temperature, in the refraction, etc., and the whole would be affected by the difference in distance and aspect at which the effect was viewed in the two cases.

But as the conditions at the surfaces of the two planets are very unlike and as dissimilar conditions would affect the relation between the twilight arc and the density dissimilarly, we cannot deduce the density from the datum of the twilight arc. We can only see in it another proof of the presence of an atmosphere of some sort or other, and regard it as giving, not a maximum, but a minimum value of such.

LOWELL OBSERVATORY.
May 7, 1895.

SPECTROSCOPIC OBSERVATIONS OF COLORED STARS.

By FRIEDRICH KRUEGER.

I BEG to communicate the following list of observations of such colored stars as either have not hitherto been examined spectroscopically, or seemed to me to require a revision on account of the dubious results of previous observers. Excepting the last three, the stars are taken from my catalogue of colored stars (*Publication VIII der Sternwarte in Kiel*), and the numbers in the following list refer to the similar numbers of that catalogue.

The observations were made with the Schroeder refractor of 266^{mm} aperture and 390^{cm} focal length belonging to the Observatory of Bamberg. Three small ocular spectroscopes, made by Otto Toepfer, of Potsdam, were employed with an eyepiece of power eighty. In some cases, where the proximity of bright stars disturbed the observations, the insertion of a diaphragm in the focus was found very helpful. On all the nights of observation the atmospheric conditions could be described as only moderately good. Since I was able to employ in my previous observations a telescope of only 216^{mm} aperture, it is possible that my present estimates of magnitude are throughout somewhat too bright. The year of all the observations is 1895.

In accordance with the suggestion of Hermann J. Klein and the practice of Schmidt, Dunér, and others, I have given the estimates of the colors of the stars in numbers (0 = white; 4 = yellow; 8 = reddish; 10 = pure red). The exponents ^{m} and ^{c} serve to distinguish between the estimates of magnitude and color. The bands are designated with numbers in the same way as by Dunér, further particulars being given in his memoir *Sur les étoiles à spectres de la troisième classe*, and in the introduction to my catalogue.

The number of known stars of classes III and IV has been

greatly increased since the appearance of my catalogue. While the number of stars between the North Pole and 23° South Declination to be regarded as certainly belonging in classes III and IV was then about 1157, now it has been increased by more than six hundred stars north of the equator. I have similarly catalogued these stars, and the list will be published as a supplement to my catalogue. In accord with a personal communication from Mr. T. E. Espin, I would also point out that all stars down to the ninth magnitude, north of the equator, which have banded spectra now seem to be known. Below this limit the number of colored stars appears to be very great, in agreement with the general abundance of the fainter stars. Knowledge of the stars having banded spectra and lying between the equator and 23° South Declination is far from complete, so that many interesting spectra will yet be found in this region.

OBSERVATIONS.

No.

67 W Cassiopeiæ.* Mar. 13 $8^e.0$ Bands.

The spectrum is too faint to permit a decision as to its type. The variability of this very red star was first pointed out by Espin, and it has been since confirmed by Hartwig.

532 U Orionis. Mar. 18 $8^e.4$ III^3.

The color is a peculiar copper-red. All the bands 1–11 are readily recognized, being very broad and distinctly cut off. Bright lines could not be seen.

706 $7^m.5$ Apr. 17 $6^e.4$ III^2.

The bands are quite broad and dark.

$7^m.3$ Apr. 22 $6^e.3$

Bands 2–8 are normally developed, quite broad, and black. The star *B.D.*+6° 1273, visible in the same field, is somewhat less intensely colored ($6^e.0$), of class II, and much brighter.

707 Apr. 17 and 22 $6^e.2$ III^2.

The spectrum is not so finely developed as that of No. 706, but bands 2–8 are all well marked, quite broad and dark.

709 $7^m.0$ Apr. 17 $6^e.0$ III^1.

Bands 2–8. Spectrum entirely normal.

* Further particulars as to its variability may be expected from Hartwig within a very short time.

714 $7^m.8$ Apr. 17 $7^c.8$ III? IV.
Red and orange portions very faint; broad gaps in green; blue visible; bands throughout the visible spectrum.

730 $7^m.0$ Apr. 17 $5^c.8$ II–III.
In red and green are two shadings, possibly strong lines.

746 $5^m.4$ Apr. 25 $5^c.0$ II^3.
Strong lines.

766 $6^m.7$ Apr. 14 $6^c.0$ III.
Bands 2–8 are normally developed.

771 $8^m.7$ Apr. 14 $5^c.8$ III?
Spectrum appears to have broad bands.

775 $7^m.3$ Apr. 14 $5^c.2$ III.
Type is normal; the bands are less sharply defined than in No. 774.

778 V Cancri. $7^m.2$ Apr. 14 $5^c.8$ III^1.
Bands 2–8 are distinct and normal.

780 $8^m.0$ Apr. 14 $5^c.6$ III.
No doubt as to type, although bands are difficult.

781 $7^m.8$ Apr. 14 $5^c.2$ III.
No doubt as to type, although bands are difficult.

792 $7^m.1$ Apr. 14 $5^c.0$ II–III.
The spectrum is certainly not purely of type II.

795 $7^m.1$ Apr. 14 $4^c.2$ II.
Of the type of α Tauri.

806 S Hydræ. Apr. 16 $6^c.0$ III.
Spectrum faint, but undoubtedly III; all the bands 2–8 are recognizable as normally developed.

810 T Hydræ. Apr. 16 $7^c.8$ IV?
Red and orange very faint, green very bright, but blue and violet almost entirely lacking; very broad and dark bands through the whole visible spectrum.

821 $7^m.0$ Apr. 16 $6^c.0$ III^1.
All the bands 2–8 are normally developed.

823 $8^m.0$ Apr. 16 $6^c.8$ III?
Bands are evident, but too faint for determining the type.

830 $7^m.0$ Apr. 16 $5^c.8$ II^1.
Hartwig estimated the color of the star on the same evening with the six-inch comet seeker as faint orange.

834 $7^m.9$ Apr. 16 $4^e.5$

No absorption bands could be recognized.

835 Apr. 16 $6^e.0$ III?

Spectrum appears similar to that of μ Ursæ majoris. Strong atmospheric undulations.

841 $6^m.4$ Apr. 12 and 16 $5^e.0$ II.

844 $6^m.4$ Apr. 12 and 16 $4^e.2$ II.

Purely solar type.

846 $7^m.9$ Apr. 12 and 16 $5^e.9$ III.

Bands 2–8 are normally developed.

852 $6^m.2$ Apr. 12 $4^e.3$ III.

Faintly developed III; bands difficult.

853 R Leonis. Apr. 12, 16, 17, 26 $8^e.6$ III^3.

On each occasion I found the spectrum to be III^3 with all the bands 1–11. All the bands were deep black, broad and sharply defined. I saw with certainty no bright line but $H\beta$; on Apr. 26 I suspected a bright line in the yellow (D).

860 $5^m.3$ Apr. 12 $7^e.8$ III^2.

Bands 2–8 are very plain, but narrow.

864 $6^m.0$ Apr. 16 $4^e.5$ II.

870 $7^m.0$ Apr. 16 $5^e.5$ III^1.

Bands are normally developed.

873 Apr. 12 $5^e.4$ II^3.

Of the solar type.

874 $6^m.0$ Apr. 16 $5^e.2$ II^2.

Of the solar type.

877 $7^m.0$ Apr. 16 $6^e.2$ III^1.

Bands 2, 3, 7 and 8 are very plain; 4 and 5 very faint.

880 $7^m.2$ Apr. 16 $5^e.8$ III^2.

In spite of low altitude all the bands 2–8 were plainly recognized.

883 Apr. 13 $5^e.0$ III^1.

All bands 2–8 are strong, but narrow.

884 $5^m.8$ Apr. 15 $6^e.2$ II–III.

Of the type of α Tauri.

886 Apr. 13 $5^e.0$ III.

Type normal; bands 2–8 are plain.

891 Apr. 15 $5^e.4$ III^1.

Type normal; bands 2–8 are plain, and quite dark.

893 $7^m.5$ Apr. 15 $6^c.0$ III?
Broad bands through the whole spectrum, but they are too faint for a certain determination of the type.

894 U Hydrae. Apr. 13 $8^c.0$ IV^3.
Red very bright; blue well seen; the characteristic bands well defined; D_3 bright?

897 Apr. 13 $4^c.6$ III.
The spectrum is indistinct, but the type can be ascertained with certainty.

898 $6^m.7$ Apr. 16 $6^c.4$ III^1.
Bands 2–8 are dark, quite broad, and well defined.

906 Apr. 12 and 15 $5^c.7$ II^2.

907 V Hydrae. $8^m.3$ Apr. 15 $8^c.5$ IV^3.
In spite of the star's faintness, its spectrum is very plain; the red and green portions are bright, as well as the yellow, but the blue is very faint.

911 $7^m.0$ Apr. 13 $5^c.4$ II? III.
Broad stripes in red and orange; probably of the type of α Tauri.

914 $6^m.6$ Apr. 13 $5^c.8$ III^1.
Type certain; band 3 is the strongest.

$6^m.5$ Apr. 15 $5^c.4$ III^2.
Bands 2–8 are all well marked and black; No. 2 and particularly 3 are very strong.

917 R Crateris. $9^m.0$ Apr. 15 $8^c.4$ III? IV.
Extremely broad and dark bands between bright zones, of which the green is the brightest and the blue very faint. I cannot estimate the color of the star so strong as Dunér, $9^c.5$.

920 $6^m.0$ Apr. 13 and 15 $4^c.0$–$3^c.8$ II.

927 $6^m.8$ Apr. 15 $5^c.6$ III^2.
Bands 2–9 are normally developed, black, and well defined. Nos. 2 and 3 are stronger than 7 and 8.

932 $7^m.3$ Apr. 15 $5^c.4$ III.
Type normal.

943 $8^m.0$ Apr. 15 $5^c.7$ III?
The bands are certainly recognizable, but the spectrum is too faint for an accurate assignment of type.

950 Apr. 15 $5^c.4$ III.
Type certain; bands difficult.

953 $7^m.2$ Apr. 15 $5^e.8$ III.
Bands dark, but indistinct. Espin's observation, "'89 March 9: $H\gamma$ and D_3 bright," is, according to his statement in a letter, erroneous.

963 $7^m.4$ Apr. 15 $5^e.8$ III.
Bands badly defined.

983 $8^m.0$ Apr. 13 $7^e.5$ III^3.
All the bands 2–9 are black, and clearly marked.

985 $7^m.7$ May 24 $5^e.5$ II? III.
Probably III. Bands sometimes suspected; image indistinct.

986 $7^m.3$ May 24 $7^e.0$ III^1.
Bands 2 and 3 are the strongest.

988 T Ursae majoris. Apr. 16 $5^e.6$ III.
Bands 2–8 can be recognized, but are not deep.

Apr. 30 $6^e.0$ III.
Bands in red and orange broad, faint and narrow in green, very broad in blue.

989 $6^m.8$ Apr. 13 $4^e.8$ II^1.
Unquestionably of the solar type.

994 On Apr. 13 and 14 I took the spectrum to be III (II), and III? respectively; with faintly developed bands, like the spectrum of μ Ursae majoris.

On Apr. 15 and 16, with better seeing, the spectrum appeared distinctly II^1 of the type of α Tauri. The color is $4^e.9$ (mean of the four observations).

995 Apr. 13 and 15 $5^e.2$ II–III.
Genuine bands are not recognized; spectrum seems similar to that of α Tauri.

1001 $8^m.5$ Apr. 13 $6^e.2$ III?
Spectrum too faint.

Apr. 15 $5^e.7$ III.
The typical bands are distinct.

1005 Apr. 13, 14, and 15 $3^e.7$ II.
Normal solar type.

1007 $6^m.0$ May 24 $5^e.8$ III.
Type of spectrum undoubted, but it is feebly developed. 2 and 3 are the only bands seen.

1011 $6^m.8$ Apr. 22 $6^e.0$ III–II.
Transition type; traces of bands are distinct.

1034 $6^m.3$ May 28 $5^c.6$ III.
The six ordinary bands are visible; those in the bluish-green are broad and deep; the others are narrow.

1036 $7^m.4$ Apr. 15 $7^c.0$ III^3.
All the bands 2–9 are broad, dark, and sharp; 2, 3, 7, and 8 are nearly equally broad and strong.

1037 $6^m.8$ May 28 $5^c.8$ III.
The bands 2–8 are feebly developed.

1038 $6^m.6$ May 28 $6^c.6$ III^1.
The bands 2–9 are easily seen, but they are neither broad nor deep.

1044 $5^m.8$ May 28 $5^c.8$ II^3.
Type of α Tauri.

1062 $6^m.5$ Apr. 30 and May 27 $6^c.0$ III.
The spectrum is fairly marked.

1066 $5^m.5$ May 27 $4^c.0$ II^3.

1067 $5^m.4$ May 28 $5^c.0$ II^1.

1068 $7^m.8$ May 28 $4^c.6$
Spectrum continuous.

1073 $7^m.2$ May 12 $6^c.6$ III?
Bands suspected; image unsteady.

1074 $6^m.0$ May 28 $6^c.0$ III^1.
The bands are visible, apparently as far as 9 inclusive; they are deep and well marked.

1075 $4^m.9$ May 29 $6^c.0$ III^3.
Very beautiful; the bands 2–9 are dark and broad throughout, 2 and 3 extremely broad and deep. Perhaps variable.

1083 $6^m.7$ May 28 $5^c.4$ II? III.
Bands suspected in the bluish-green.

1091 D'Arrest considered this spectrum as one of the finest. In agreement with the observations of Dunér in 1880–84, and mine in 1891, I find the type to be still only III^1, on Apr. 17 and 30. Bands 2–9 are visible; they are black and distinct, but, excepting 2 and 3, are narrow. Color $5^c.8$.

1092 May 27 $6^c.0$ II^2.
Fine orange.

1094 $6^m.8$ May 12 $4^c.0$
Spectrum apparently continuous.

1096 $8^m.2$ May 28
Color and spectrum doubtfu

1098		May 28	$5^{e}.6$	III.
	Bands pale.			
1116		May 28	$4^{e}.8$	II.
	$H\gamma$ very strong.			
1120		May 28	$3^{e}.5$	I (II)
	Many fine lines, the hydrogen lines very distinct.			
1123	$8^{m}.0$	May 28		
	Color not pronounced; spectrum very faint; bands not visible.			
1127	$6^{m}.4$	May 28	$4^{e}.0$	II^{2}.
1130	$8^{m}.0$	May 28	$6^{e}.0$	III^{2}.
	The bands 2–8 are very well marked, broad and dark.			
1133		May 28	$3^{e}.5$	II.
1136	$5^{m}.5$	Apr. 22	$6^{e}.5$	II^{3}.
1139	$6^{m}.8$	Apr. 22	$7^{e}.0$	III^{3}.
	All the bands are normal; deep, black, and distinct.			
1147	$6^{m}.5$	May 28	$4^{e}.7$	II^{1}.
1152	$6^{m}.0$	Apr. 22	$3^{e}.0$	II^{3}.
1162	S Coronæ. $8^{m}.0$	Apr. 30	$6^{e}.8$	III.
	Bands 2–8 can be recognized, but only with difficulty.			
1172	$6^{m}.5$	Apr. 22	$4^{e}.5$	II.
	Of the solar type.			
1178	$6^{m}.6$	May 28	$6^{e}.7$	III^{2}.
	The bands are broad and deep throughout the spectrum as far as 9 inclusive; 2 and 3 are as strong as 7 and 8.			
1185	$5^{m}.0$	Apr. 30	$7^{e}.0$	III^{2}.
	Bands 2–9 are easily recognized, well defined and dark; 2 and 3 are very strong; 7 and 8 somewhat fainter; 4 and 5 are plain in spite of strong atmospheric undulations. Spectrum is similar to that of 1091.			
1196	$5^{m}.5$	May 27	$4^{e}.2$	II^{2}.
1214	$4^{m}.8$	Apr. 30	$5^{e}.2$	II^{3}.
	The type is that of α Tauri.			
1224	$5^{m}.5$	Apr. 30	$6^{e}.0$	III.
	The narrow bands are well indicated, but are not very dark. They are visible into the violet.			
1296	$6^{m}.8$	May 28	$6^{e}.8$	III^{1}.
	The bands are visible as far as the blue; they are broad, but not deep.			

1372 $7^m.2$ May 28 $6^e.5$ III.
The bands are broad throughout the entire spectrum.

1638 $7^m.0$ May 24 $5^e.2$ III.
The bands 2–8 are visible; those in the bluish-green are strongest.

1643 $7^m.0$ May 24 $5^e.4$ II? III.

1649 $4^m.0$ May 24 $5^e.6$ II.
Solar type.

1661 $8^m.0$ May 24
Color not pronounced; spectrum too faint for observation.

1685 $7^m.3$ May 24 $5^e.7$ III?
Faint bands.

1941 $5^m.0$ May 23 $4^e.7$ II^1.

1949 Espin says (*A.N.* 3286), 1894, July 5, II? "with higher dispersion certainly II." I have reëxamined the spectrum, on May 20 and 23, and have found it to be undoubtedly III. The bands 2–10 are visible and well marked, but not broad and deep. The spectrum is but feebly developed.

1970 $5^m.3$ May 23 $4^e.0$ II^2.

— *B.D.*+52°1362. $7^m.5$ Apr. 22 and May 10 $4^e.1$ II.
Bands are certainly not visible. Espin, 1893, Mar. 22: $7^m.0$, OR^1, III^1.

— *B.D.*+43°1943. $6^m.9$ May 10 $4^e.0$ II^1
Certainly not III. Espin, 1893, Mar. 13: $7^m.3$, OR, III^1.

2141 R Cassiopeiæi. Mar. 17 $7^e.5$ III^1.
Bands 2–8 are easily recognized, though faint and narrow.

— U Arietis. 1894 Oct. 21 $6^e.4$ III^2.
Bands 2–9 are readily recognized, being black and well marked, as are 4 and 5.

— *B.D.*+35°1635. $7^m.0$ Apr. 22 $5^e.9$ III^1.
Bands 2–8 are well shown, dark and rather broad. In the Lund zones the star was observed on 1880, Jan. 24, and 1893, Jan. 25, respectively as 7.0, yellowish-red, and 7.5, reddish-yellow.

— *B.D.*+36°1726. $7^m.2$ Apr. 22 $6^e.2$ III^2.
Bands 2–8 are broad, black, and very well marked. In the Lund zones the star was observed on 1880, Jan. 24, and 1893, Apr. 8, as $6^m.8$ and $6^m.0$, and yellowish-red.

A few stars of the catalogue have been also re-observed elsewhere, and I add these observations so far as they have come to

my notice. With these I also give the additions and corrections which have come out as the catalogue has been used. For most of the corrections I have to thank Mr. T. E. Espin.

In the list *E*=T. E. Espin; *G. & L.*=G. Gruss and W. Láska (*Beobachtungen heller Linien in den Spectren einiger Sterne, angestellt mit dem Achtzöller des astronomisches Institutes der böhmischen Universität zu Prag*); *Hg*=Hartwig; *K*=Krueger; *Pe*=Pechüle (*Expedition Danoise pour l'observation du passage de Vénus*, Copenhague, 1883).

No. *16:* *E* III¹. *33:* *Pe*, 1882, Dec. 4, dark orange, a fine III. *84:* The star observed by *E* is not *B.D.*+52°251, but 241, mag. in *B.D.* 7.5. The position for 1900 is $0^h57^m16^s+51°\ 15'.7$; *E*, 1893, Dec. 1, 8ᵐ.0, OR¹, III²; *K*, 1894, Dec. 2, 7ᵐ.8, 5ᶜ.6, III¹. *85:* *E*, 1891, Dec. 22, 9ᵐ.3, OR¹, III? faint. *140:* The star observed by *E* is *B.D.* +53°398, 8ᵐ.5. The position for 1900 is $1^h\ 44^m\ 0^s+53°\ 14'.7$; *E*, 1893, Oct. 11, 8ᵐ.0, OR, III³. *148:* *E*, 1892, Jan. 1, 8ᵐ.0, OR, III¹. *187:* for R.A. $2^h\ 14^m\ 57^s$ read $2^h\ 15^m\ 20^s$. *190:* *E*, 1892, Jan. 1, 8ᵐ.0, OR, III¹. *210:* *E*, 1888, Dec. 26, 8ᵐ.8, RR, bands. *228* is W Persei. *255:* *E*, 1893, Mar. 18, 8ᵐ.6, OR, III. *262:* *E*, 1893, Mar. 18, 8ᵐ.0, R, IV³; *K*, 1894, Dec. 2, 7ᶜ.5, IV³. *264:* *E*, 1893, Mar. 18, 7ᵐ.3, OR, III¹; *K*, 1894, Dec. 2, 7ᵐ.2, 5ᶜ.7, III normally developed. *308:* Espin's observation applies to *B.D.*+61°690, 7ᵐ.0, whose place for 1900 is $4^h\ 8^m\ 50^s+62°\ 5'.9$. *337:* *E's* observation applies to *B.D.*+56°898, 8ᵐ.7, whose place for 1900 is $4^h\ 8^m\ 42^s+56°\ 59'.5$. *356:* *E*, 1893, Mar. 18, 7ᵐ.9, RR, III³, var.? *377* is to be stricken out; *E's* observation probably refers to *378;* under *378* the words "1892, Jan. 1: 8ᵐ.0, OR, III" are to be stricken out, and add: "*E*, 1893, Dec. 1: 9ᵐ.2, R¹. *392:* The remark quoted by me from Bm_2 is incorrect in Bm_3, and should be stricken out. *409:* The star observed by *E* is *B.D.*+57°845, 8ᵐ.5, whose place for 1900 is $4^h\ 48^m\ 4^s+57°\ 58'.2$. *443:* Lund zones, 1881, Feb. 24, 8ᵐ.7, RR. *500* is U Aurigæ. *557* varies through one magnitude, according to Backhouse. *579* is V Aurigæ. *592:* *E* does not consider that this can have been confounded with *B.D.*+19°1348. *632:* The position for 1900 given by *E* is $6^h\ 42^m\ 27^s+0°\ 47'.5$, the star not occurring in the *B.D.* *E* does not consider a confusion with +0°1600 to be possible. *648:* Pechüle's observation reads: 1882, Dec. 7, rather reddish, II? *652:* *Pe*, 1882, Dec. 7, somewhat reddish, spectrum continuous. *664:* *E*, 1893, April 3, 9ᵐ.0, R¹, III¹. *707:* *E*,

1893, Apr. 28, $7^m.0$, OR, III^3. *712:* *E*, 1893, Mar. 28, $8^m.0$, OR, III^3, var.? *735:* Under Baxendall should be added: "It was examined with the spectroscope at Lord Lindsay's Observatory, but showed no peculiarity, and no particular color seemed to predominate in its spectrum." *760* is *Bm*, 192. *811:* *G.* & *L.*, 1894, May 6, III^1, red color strongly conspicuous. *829:* On 1883, Jan. 5, *Pe* did not find the star; Jan. 6, $8^m.9$, rather reddish, spectrum faint; in March and April, 1895, I have repeatedly searched for the star, but without success. *853:* *G.* & *L.*, 1894, May 6, after the maximum. *Hβ* and perhaps also *Hα* bright; D_3 bright! Very transparent air. May 8, *Hα* bright; *Hβ* and *Hγ* certainly not; bands easily seen. May 28, *Hβ* bright. June 1, *Hα* certainly bright. *890:* *E*, 1893, Mar. 13, $7^m.0$, OR, III^1. *934:* Under *E*, for IV write III. *964:* *Pe*, 1883, Jan. 6, somewhat orange, spectrum continuous. *1043:* The observation of *Pe* reads, "1883, Jan. 5, white, spectrum continuous." *1054:* *Pe*, 1883, Jan. 6, very red; spectrum banded, but too faint to decide whether III or IV. *1065:* *E*, 1888, Jan. 26, a fine orange, III, bands not deep; 1889, Jan. 23, *Hβ* bright? 1892, Apr. 22, *Hβ* again suspected as bright, bands in red are strong, but in other portions weak. *1079:* *E*, 1893, Apr. 9, $7^m.0$, OR^1, III^2. *1082:* *E*, 1889, Mar. 28, $8^m.7$, R, III^3, very deep bands. *1108:* Variable according to *Hg*. *1115:* *E*, 1888, Apr. 6, $7^m.7$, R, III^3; *G.* & *L.*, 1894, June 30. *Hβ* exceptionally bright; *Hα* occasionally appears bright; the spectrum is wonderfully developed; July 5, *Hα* bright. *1195* and *1211:* Consult *E* in *A.N.* 3200. *1244:* *G.* & *L.*, 1894, June 30 and July 5, III^2. *1382:* *E*, 1893, Aug. 19, $9^m.0$, R, III? *1383:* *E*, 1893, Aug. 19, $8^m.7$, R, IV? *1385:* *E*, 1893, Aug. 19, $9^m.0$, R, IV? *1444:* de Ball, 1892, July 19, $8^m.4$, R^2; *K*, 1894, Sept. 15, $7^c.4$, IV^2. *1450:* *E*, 1893, Aug. 19, $8^m.3$, R, III^3; *K*, 1894, Sept. —: $8^m.0$, $6^c.6$, III^2; bands are dark and broad. *1463:* According to later observations by Espin and myself the star *B.D.*$+36^\circ$ 3239 is white and of class I. The position given by Gage is 10^s preceding and $3'$ S. Espin did not see the star in 1886–88. There was probably a mistaken identification by me. *1467* is variable according to Espin. *1470:* Under *Sa* add: $6^m.9$, not variable. *1474:* *G.* & *L.*, 1894, July 6, III, spectrum not marked but easily identified. *1478:* *E*, 1893, Aug. 19, $7^m.0$, OR, III^1. *1498:* *G.* & *L.*, 1894, July 6, III^3; also on July 28 no bright lines were seen. *1513* is V Aquilæ. *G.* & *L.*, 1894, July 6, IV, bands well seen, red prominent. *1520:* *G.* & *L.*, 1894, June 23, *Hα*, *Hβ*, *Hγ* and D_3, bright; June 30, *Hα*, *Hβ*, *Hγ*,

bright; July 2, *Hα* very bright, uncertain whether *Hβ*, *Hγ* and D_3 are bright; July 5, *Hβ* seen bright only briefly, D_3 certainly bright; July 6, no bright lines. *1592:* *G. & L.*, 1894, June 23, D_3 perhaps bright, type seems not to be III but II. *1594:* *E*, 1892, Jan. 1, $7^m.5$, OR^1, III^1; *K*, 1892, Jan. 15, $5^e.4$, III. *1646:* Under *E* instead of III^3 read III? *1655:* The star observed by *E* is *B.D.*$+20^\circ$ 4390, whose place for 1900 is $20^h\ 17^m\ 57^s+20^\circ\ 48'.5$. *1668* and *1672:* *E* makes the remark "misidentified?" *1682:* Lund zones, 1881, Aug. 16 and 18, $7^m.7$ and $7^m.8$, R^2. *1683:* *Hg* confirms variability (see *A.N.* 3191 and 3211). *1690:* *E*, 1893, Sept. 16, 11^m, RR, IV^1. *1699* is RS Cygni. *1701:* *G. & L.*, 1894, July 23, III. *1722:* Lund zones, 1881, Oct. 7, $6^m.7$, reddish-yellow; Oct. 14 and 16, $6^m.5$ GR, and $6^m.0$ RG. *1727:* Under *E* strike out the words "1891, Sept. 12, $9^m.2$, OR, B, III?" *1729:* *E*, 1893, Sept. 16, $9^m.2$, IV? *1749:* The declination is $+11^\circ\ 44'.7$, not $4'.7$. *1795* is U Delphini. *1802:* *E*, 1893, Sept. 9, R, III^2. *1803* is V Delphini. *Hg*, R^2. *1942:* Under *E* the words "$9^m.5$ bis IV?" are to be stricken out, and "not identified" substituted; 1893, Sept. 16," not seen." *1943:* Under *E* add: a broad band; 1893, Sept. 16, $9^m.2$, R, III^2. *1955:* *E*, 1893, Sept. 19, $8^m.7$, RR, IV peculiar, 9 extraordinarily intense. *1975:* *E*, Oct. 3, $8^m.7$, OR^1, III^1. *1978:* *E*, 1887, Sept. 18, $7^m.5$, R^1, III^3. *2037:* *Pe*, 1882, Dec. 7, III feebly developed?" *2039:* The star observed by *E* is *B.D.* $+54^\circ 2863$, $9^m.5$, whose place for 1900 is $22^h\ 43^m\ 40^s+54^\circ\ 38'.0$; instead of IV? under *E*, read III^3; *E*, 1893, Oct. 8, R, III^3, var. *2061:* *E*, 1887, Oct. 15, $7^m.5$, R^1, III^2. *2079:* The star observed by *E* is *B.D.*$+52^\circ 3386$, $9^m.1$, whose place for 1900 is $23^h\ 7^m\ 1^s+52^\circ\ 21'.0$; *E*, 1893, Oct. 8, $9^m.0$, R, III^3. *2102:* The star observed by *E* is *B.D.* $+52^\circ 3440$; *E*, 1893, Oct. 8, $7^m.3$, OR^1, III^1. *2153:* The star observed by *E* is *B.D.*$+42^\circ$ 4827, $8^m.4$, whose place for 1900 is $23^h\ 59^m\ 28^s+42^\circ\ 59'.7$.

The following numbers refer to the *Nachtrag*, p. 142 of the catalogue. *15:* *E*, 1893, Dec. 11, $8^m.6$, R, III^2. *16:* *K*, 1894, Oct. 21, $6^e.8$, III^2. *18:* *E*, 1892, Jan. 1, $8^m.5$, OR, III. *42* is *B.D.*$+40^\circ 1310$. *56* is *B.D.*$+24^\circ$ 1386, $7^m.8$; the positions of these two are correct. *68:* *E*, 1892, Apr. 22, $6^m.8$, OR, III. *122* is W Aquarii. *129:* Lund zones, 1880, Sept. 26 and 27, $7^m.7$ and $7^m.4$, GR.

BAMBERG, May 2, 1895.

Minor Contributions and Notes.

NOTICE.

Attention is called to the fact that The Astrophysical Journal is not issued in July or September. The next number will be published October 1.

PRELIMINARY NOTE ON THE RADIATION OF INCANDESCENT PLATINUM.

If we determine the curve of energy in the spectrum of an incandescent solid we find that it varies with the temperature of the radiating body. What is the nature of this variation? Is it merely a proportional increase of energy in all parts of the spectrum, or does the amount in the shorter wave-lengths increase in a greater proportion than that in the longer as the temperature of the source becomes higher? If the latter is true, the position of maximum energy in the spectrum would shift toward the violet end; if the former, there would be no shifting of the curve. This point has been carefully studied by Dr. Jacques in this laboratory, and by Professor Langley, in Allegheny, with opposite results. Professor Lecher, by a null method, though not a very accurate one, discovered no shift.

The following very accurate null method suggested itself to me, and was tried: Two bolometers were so connected that when heated they would produce deflections of the galvanometer in opposite directions; if equally heated, no deflection would be produced. The spectrum of an incandescent platinum strip, heated by an electric current to a nearly white heat, was formed by a rock-salt prism and lens, and the bolometers so placed in this spectrum, on opposite sides of the point of maximum energy, that they received equal amounts of heat and caused no deflection of the galvanometer. The current was now diminished until the radiating platinum was of a dull red color; there was an immediate deflection of the galvanometer indicating a shifting of the energy curve toward the longer wave-lengths. By moving a screen partially in front of the projecting lens I found that this result was not produced by a diminution of the amount of heat falling on

the bolometers so long as the temperature of the radiating source was unchanged. This result, which does not depend on the comparison of very similar curves obtained at different times, is decisive that the energy curve of incandescent platinum shifts toward the shorter wave-lengths as the temperature of the source increases. This is in accordance with Professor Langley's observations.

The following optical methods gave the same result: Two platinum strips were placed one vertically above the other and heated to different temperatures. Their images were projected on the slit of a spectroscope; by narrowing the slit in that portion where the brighter image fell, the two spectra could be brought to about the same intensity, say in the red; the spectrum of the hotter strip was then found to be brighter, and to be visible further, in the violet, than that of the other. This experiment was tried both with a grating and with a prism, but the result could only be made out with difficulty. Another form of experiment was more satisfactory; the images of two incandescent platinum strips were projected side by side on a sheet of white paper by two lenses; by partially covering one of the lenses by a screen the images could be made equally bright; that of the hotter strip was not nearly as red as the other. Incandescent carbon lamps gave similar results. In all these optical experiments the strips were interchanged, so that sometimes one and sometimes the other was the hotter; the hotter always radiated a larger proportion of energy of the shorter wave-lengths.

This work will be continued next winter, and the more important determination of the distribution of energy in the spectrum of a theoretically black body will be made. It by no means follows from the above experiments that the energy curve of such a body will shift with the temperature. It is curious that a really black body, the most important in the theory of radiation, has not so far been used by experimenters.

HARRY FIELDING REID.

PHYSICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
June 10, 1895.

THE VISIBLE SPECTRUM OF THE TRIFID NEBULA.

MISS CLERKE's paper in the May *Observatory* on "Some Anomalous Sidereal Spectra" calls attention to the discordant observations of the Trifid Nebula spectrum by the Harvard College observers in 1869–1873, by Father Secchi, and by Professor Keeler in 1890; and

I am thereby reminded that it would be well to publish my observation of that nebula made last year.

On August 3, 1894 I had occasion to examine several of the Harvard "bright *Hβ*" stars, to see if they also had bright *Hα* lines. In setting the telescope for the bright *Hβ* star *A. G. C.* 24550, the finder field also contained the Trifid Nebula and *N. G. C.* 6523, and the spectra of the nebulæ were examined.

The visible spectrum of the Trifid Nebula consists of continuous spectrum and the three usual lines at λ 5007, λ 4959 and λ 4862 (*Hβ*). These lines are easily visible, and it was at once seen that the *Hβ* line is relatively very strong in this nebula. In many parts of the nebula, especially the faint outlying portions, the *Hβ* line is brighter than λ 5007; while in other portions, especially in the denser central parts, the λ 5007 line is brighter than the *Hβ* line. The lines λ 5007 and λ 4959 have about their usual relative intensities of 3 or 4 to 1. Whether or not the continuous spectrum is unusally strong, I am unable to say; but I think it is little if any stronger than we would expect from a gaseous nebula. A safe estimate on that point could not be made on August 3, 1894, nor on the date of a recent observation, May 24, 1895, because on both occasions the spectra of the aurora borealis and of the sky light were visible, along with the spectrum of the nebula. The principal aurora line, at λ 5571, was fully as prominent as the nebular line at λ 4959.

W. W. CAMPBELL.

May 27, 1895.

NOTE ON THE SPECTRUM OF THE AURORA BOREALIS.

VISUAL observations of faint nebular and comet spectra are often interfered with by the aurora and sky spectra. It is possible to see the principal line in the aurora spectrum on almost any dark clear night. I have looked for it in all parts of the sky on at least a dozen occasions, always with success. It has occurred to me that possibly some of the faint lines photographed in nebular and comet spectra, with very long exposures, may have their origin not in the nebulæ and comets but in the aurora. At least it would seem worth while to test the question by making long exposures on some portion of the sky free from nebulous matter when an aurora is present.

W. W. CAMPBELL.

May 27, 1895.

OBSERVATIONS OF THE B BAND IN STELLAR SPECTRA.

In connection with my work on the spectrum of Mars I had occasion in July 1894, to examine the spectra of several stars with reference to the bands introduced by the absorption of our own atmosphere. The principal telluric bands seen in stellar spectra by Professor Vogel in 1873 were observed, and the additional band B was seen with extreme ease in the spectrum of every star examined — Vega, Arcturus, Altair, Alcyone. B was easy in Vega when that star was within a degree of the zenith, but less prominent than when the star was low in the sky. So far as I know, the B band had not been previously observed in stellar spectra. Since it exists in stars of widely different types, and changes its intensity as the altitudes of the stars vary, these observations support the theory of the telluric origin of the B band.

May 27, 1895. W. W. CAMPBELL.

NOTE ON THE SPECTROSCOPIC PROOF OF THE METEORIC CONSTITUTION OF SATURN'S RINGS.

In an interesting paper communicated to the French Academy of Sciences (*C. R.* **120,** 1155) M. Deslandres describes some spectroscopic observations of Saturn similar to those which I published in a previous number of this JOURNAL, but states that he differs from me in not regarding them as strictly furnishing a proof of the meteoric structure of the ring. I do not think, however, that we really differ on this point. The objection raised by M. Deslandres, although it is worth pointing out, is purely formal, and does not affect one's conviction that the proper interpretation has been put upon the observations. I quite agree with M. Deslandres that the spectroscope is incapable of distinguishing between (1) a ring made up of an infinite number of infinitely narrow concentric rings, or even one made up of a considerable number of concentric solid rings of finite width (the number increasing with the perfection of the photograph), and (2) a ring composed of separate particles. We are, however, limited by the evidence to a choice between these alternatives. The first leads to such an artificial conception of the ring that it would be immediately rejected in favor of the second, even if all information derived from other sources should be disregarded. Admitting this outside information (and the application of spectroscopic methods in general requires such a course), there is no room whatever for doubt as to which alternative must be chosen.

From the point of view which I have taken in my previous articles, the question as to the form of a line in the spectrum of a divided ring may be regarded as follows: With a finite number of concentric solid rings the spectral lines would have a stairway-like structure, made up of a number of short lines having the equations $y=mx$, $y=m'x$, $y=m''x$, etc., in which the values of m decrease continuously from the inside to the outside of the ring. The center of each short line (or a point very near the center) would lie on the curve $y=kx^{-\frac{1}{2}}$, which would be the limiting form of the line corresponding to an indefinite increase in the number of subdivisions of the ring.

Since my first paper on this subject was printed, I have succeeded in obtaining some photographs with a slit-width of $0.^{mm}020$, on which the inclination of the lines in the spectra of the ansæ is quite easily measurable. The results agree well with theory, but I will not give the measures, as photographs recently obtained by Professor Campbell with the Lick telescope and described in the present number furnish the same results with a much greater degree of accuracy.

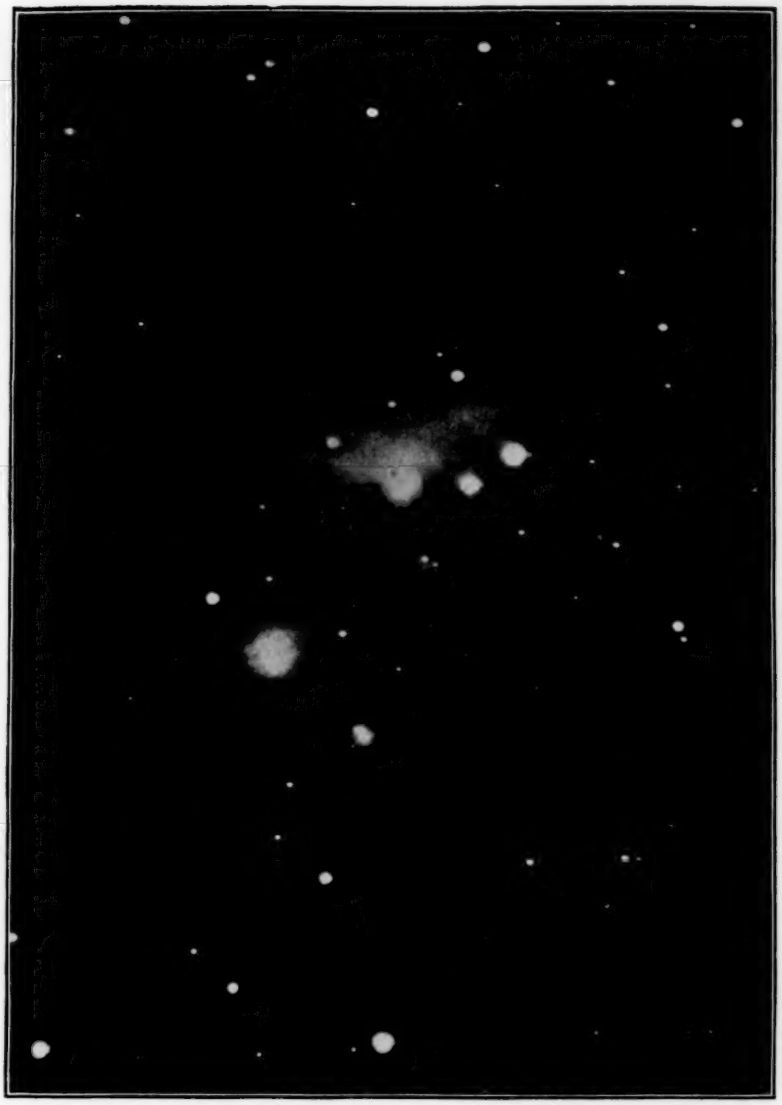
I may add here that my photographs of 1893, referred to in a previous paper, gave a rough determination of the mean velocity of the ring, although I considered that such a very meager result was not of sufficient interest for publication. Notwithstanding the poor quality of the photographs, the doubling of the displacement due to reflection was apparent; but the existence of such an effect seemed to be well recognized, and to have been proved experimentally by the numerous measures of the rotation of Jupiter and of the rings of Saturn made at Greenwich and published in the *Spectroscopic Results*, although the precision of these visual measures is, of course, greatly inferior to that of modern photographic methods. The necessity mentioned by M. Deslandres for regarding specularly reflected and irregularly reflected light as two different cases requiring independent proof is not quite clear to me.

JAMES E. KEELER.

PHOTOGRAPH OF THE NEBULA NEAR 42 ORIONIS MADE AT THE ASTROPHYSICAL OBSERVATORY OF CATANIA.

THIS photograph was made with the photographic equatorial of $0^m.328$ aperture with an exposure of $4^h\ 8^m$ on a Lumière plate. The enlargement reproduced in Plate VIII was obtained in two photographic cameras placed opposite one another, with a Voigtländer objective

PLATE VIII



PHOTOGRAPH OF THE NEBULA NEAR 42 ORIONIS

By A. Riccò, Catania Observatory

interposed, the illumination being derived from the diffuse light of the northern sky.

The very interesting structure of this nebula is much better shown in the photograph than in drawings. This has been demonstrated by a comparison with the remarkably fine drawings of Tempel. The great brightness of the stars in the nebula renders very difficult the perception of the details of the surrounding nebulosity.

Particularly noticeable are the nebulous streaks which radiate from the nebulous stars and seem to join together these and the other nebulosities; also the black mouth, open to the south, with its well-marked lip.

A. RICCÒ.

CATANIA, SICILY,
May 12, 1895.

NOTE ON THE D_3 LINE IN THE SPECTRUM OF THE CHROMOSPHERE.

IN *Nature* for June 6, 1895, Professor Runge describes the observations made by himself and Professor Paschen of the bright yellow line in the spectrum of the gas obtained from clèveite. Using a concave grating of 6.5 meters radius they found the line to be double, the wave-lengths of the bright and faint components being 5875.883 and 5876.206 respectively. Professor Rowland's value for the wave-length of the D_3 line in the spectrum of the chromosphere is 5875.982, and no mention is made in his Table of Standard Wave-lengths of any appearance of duplicity. The small probable errors of both sets of determinations justified Professor Runge in declining to accept Mr. Crooke's conclusion "that the unknown element helium causing the line D_3 to appear in the solar spectrum is identical with the gas in clèveite, *unless D_3 is shown to be double.*"

After reading this note I immediately examined the D_3 line in the spectrum of a very bright prominence which fortunately happened to be on the limb. In the fourth order of a 14438 grating the line was at once seen to have a faint companion on the less refrangible side. Measures of the distance between the lines made by my assistant Mr. Ellerman and myself gave:

June 20,	Hale,	0.354	tenth-meters
June 20,	Ellerman,	0.359	"
June 21,	Hale,	0.357	"
Mean,		0.357	

This result differs from Professor Runge's value by 0.034 tenth-meters. I regret that on account of the exceptionally cloudy and hazy weather which has since prevailed I have had no opportunity to repeat these measures.

I have satisfied myself by careful observations of the atmospheric lines considered by Bélopolsky to be the cause of the duplicity of D_3 observed by him in 1891, that this explanation properly applies only to an apparent companion to D_3 sometimes seen on the more refrangible side. Both members of the telluric pair mentioned by Bélopolsky are *below* the companion I have measured.

The observations of the duplicity of D_3 have been confirmed by Dr. Huggins and by Professor Taylor Reed.

The displacement of the line caused by the motion of the prominence in the line of sight not being accurately known it was thought best to measure the wave-length of the principal component in the chromosphere at the north and south poles of the Sun. D_3 is about 0.52 tenth-meters wide under these conditions, and on account of the unsteadiness of the spectrum at the limb the wave-length of its center cannot be measured with great accuracy. Two independent measures made by myself at the north and south poles in the fourth and second orders of the grating gave 5875.928 and 5875.920 respectively. In spite of the increased width of both components I have under favorable conditions seen traces of duplicity in the chromosphere. The presence of the faint companion on the less refrangible side would tend to increase the measured wave-length of the principal line, and this may account for the difference between Professor Runge's value and my own. This supposition is perhaps indicated by the fact that the mean of Mr. Ellerman's measures (5875.908) is somewhat smaller than my own, while faint and difficult lines are always more clearly visible to me than to him. As soon as opportunity offers I hope to repeat my determinations of the wave-length under more favorable conditions. The present results are to be regarded as preliminary.

GEORGE E. HALE.

ÉTIENNE-LÉOPOLD TROUVELOT.

E. L. TROUVELOT was born at Guyan court, Aisne, France, December 26, 1827. From his early youth he gave evidence of the pronounced taste for drawing which he subsequently found of such value in his

scientific work. His participation in the events connected with the Coup d'État caused him to be exiled to the United States in 1852. He established himself in Boston, where he acquired the friendship of Louis Agassiz. During this period he made a large number of drawings to illustrate various subjects of entomology, ornithology, etc. As an active member of the Boston Society of Natural History he published in its annals a series of papers dealing for the most part with his entomological investigations.

His interest in astronomy was awakened in 1870, when the occurrence of a remarkable series of auroras led him to purchase a small telescope. His excellent drawings of the Sun, planets and other objects soon brought him to the attention of the astronomers of Harvard College Observatory, of which Professor Winlock was then Director. At his request M. Trouvelot joined the staff of the Observatory, and continued his observations there for several years. During the latter part of his stay in America he carried on his work in his private observatory. While at Harvard many of his observations of the Sun, planets, shooting stars, auroras, etc., were published in Volumes VIII and IX of the *Annals*.

In 1878 M. Trouvelot, accompanied by his son, observed the total solar eclipse as members of Professor Harkness' party at Creston, Wyoming. Their results were published with those of the American observers in *Washington Observations* for 1876, *Appendix* III.

In 1882 M. Trouvelot was appointed Astronomer at the Astrophysical Observatory of Meudon, where he continued his investigations up to the time of his death. In 1883 he was a member of the French eclipse expedition to Caroline Island.

The long list of papers published by M. Trouvelot between 1870 and 1894 comprises over eighty-five titles. Among the more important of these publications may be mentioned the well-known series of astronomical drawings, with manual, and a monograph containing 100 drawings of Venus and Mercury. Numerous articles and drawings, including a monograph on Mars, were left in manuscript. It is interesting to know that some of these will be published by his son.

M. Trouvelot was a member of several learned societies. In recognition of his contributions to astronomy he received, among other distinctions, the Valz Prize of the French Academy of Sciences.

He died at his home in Meudon April 22, 1895.[1]

[1] For the facts embodied in the above note we are indebted to M. Georges Trouvelot.

THE BELGIAN ASTRONOMICAL SOCIETY.

THE foundation of an astronomical society in Belgium is satisfactory evidence that the spirit which has led to the formation of the Astronomical Society of the Pacific, the British Astronomical Association, and the Astronomical Society of France, is fast gaining ground upon the Continent. In its first publication the new Society announces its purpose "to labor for the popularization of astronomy and the related sciences; to establish a center to which shall be communicated observations and discoveries made in all parts of the world; to encourage research by every possible means." The General Council, established under the presidency of M. Fernand Jacobs, comprises among other well-known names those of MM. Lagrange, Stroobant and Terby. Meetings of the Society are to be held on the first Monday of every month at the *Hotel Communal de Saint-Josse-ten-Noode, avenue de l'Astronomie*, Brussels.

The new society cannot fail to contribute largely to the advancement of astronomy in Belgium. We wish it every success in its efforts.

CHANGE OF ADDRESS.

ON account of unforseen delays in the construction of the Yerkes Observatory, Professor Hale will probably return to Chicago for the winter. His address will remain *Yerkes Observatory, Lake Geneva, Williams Bay P. O., Wisconsin*, until September 1, after which it will be *Kenwood Observatory, Chicago.*

Recent Publications.

A list of the titles of recent publications on astrophysical and allied subjects will be printed in each number of The Astrophysical Journal. In order that these bibliographies may be as complete as possible, authors are requested to send copies of their papers to both Editors.

For convenience of reference, the titles are classified in thirteen sections.

1. The Sun.

Adams, A. J S. Note on Apparent Umbral Protrusion and its effect upon Foreshortening in Solar Spots. Jour. B. A. A. **5**, 302, 1895.

Evershed, J. Solar Spectroscopic Report for 1894. Jour. B. A. A. **5**, 345–349, 1895.

Gore, J. E. The Sun's Stellar Magnitude. Knowl. **18**, 130–132, 1895.

Guillaume, J. Observations du Soleil faites à l'observatoire de Lyon, pendant le premier trimestre de 1895. C. R. **120**, 1250, 1895.

Guillaume, J. Le Soleil pendant le premier trimestre de 1895. Bull. Soc. Astr. France, **1**, 224–226, 1895.

Lockyer, J. Norman. The Sun's Place in Nature, VI. Nat. **52**, 156–158, 1895; VII. Nat. **52**, 204–207, 1895.

Mascari, A. Protuberanze solari osservate nel Regio Osservatorio di Catania nell'anno 1894. Mem. Spettr. Ital. **24**, 61–79, 1895.

Oppolzer, E. von. Reviews of, August Schmidt, Die Strahlbrechung auf der Sonne; Otto Knopf, Die Schmidt'sche Sonnentheorie. Viert. Astr. Gesell. **30**, 24–39, 1895.

Scheiner, J. Review of, E. von Oppolzer: Ueber die Theorie der Sonnenflecken. Viert. Astr. Gesell. **30**, 15–24, 1895.

Tacchini, P. Sulla distribuzione in latitudine dei fenomeni solari osservati al Regio Osservatorio del Collegio Romano nel 1° trimestre del 1895. Mem. Spettr. Ital. **24**, 85–95, 1895.

Townsend, John S. Rough Balance Sheet of Sun-spot Ledger of 1893. Jour. B. A. A. **5**, 407, 1895.

Wilsing, J. Bemerkung zu dem Aufsatz des Herrn W. Stratonoff: "Bestimmung der Rotationsbewegung der Sonne aus Fackelpositionen." A. N. **137**, 385–387, 1895.

——— Local Particulars of the Total Eclipse of the Sun, 1898, Jan. 21–22. Naut. Alm. Circ. No. 16.

3. Stars and Stellar Photometry.

Chandler, S. C. Revised Supplement to Second Catalogue of Variable Stars. A. J. No. 347, **15**, 81–85, 1895.

Editor Obs'y. Algol. Obs'y, **18**, 229–231, 1895.

Gemmill, S. M. B. The Milky Way. Jour. B. A. A. **5**, 303–305, 1895.

Gruss, G. und W. Láska. Untersuchungen über den Lichtwechsel von veränderlichen Sternen. Sirius, **23**, 153–158, 1895.

Gruss, G. and V. Láska. Maxima and Minima of Variable Stars Observed in 1894–5. A. J. No. 348, **15**, 91–92, 1895.

Innes, R. T. A. The Order of Brightness of First Magnitude Stars. Jour. B. A. A. **5**, 402–405, 1895.

Markwick, E. E. Notes on the Variable Stars X and W Sagittarii. M. N. **55**, 338–341, 1895.

Maunder, E. Walter. Dr. Roberts' Photographs of Star-Clusters and Nebulæ. Knowl. **18**, 155, 1895.

Parkhurst, Henry M. Notes on Variable Stars, No. 8. A. J. No. 346, **15**, 76–77, 1895.

Schur, W. Helligkeitsschätzungen von T (nova) Aurigæ. A. N. **138**, 109–111, 1895.

Waugh, W. R. Stellar Chromatics. Obs'y **18**, 234, 1895.

Yendell, Paul S. On the Light-Curve of 103 T Andromedæ. A. J. No. 348, **15**, 92–96, 1895.

Yendell, Paul S. Observations of Suspected Variables, 1893–5. A. J. No. 346, **15**, 78–79, 1895.

Yendell, Paul S. Ephemeris of Variables of the Algol-Type. A. J. No. 345, **15**, 72, 1895.

4. Stellar Spectra, Displacements of Lines and Motions in the Line of Sight.

Espin, T. E. Stars with Remarkable Spectra. A. N. **137**, 369–375, 1895.

Krüger, Friedrich. Bemerkung zu Espin "Stars with Remarkable Spectra" in A. N. 3286. A. N. **138**, 111, 1895.

Monck, W. H. S. The Spectra and Colors of Double Stars. Jour. B. A. A. **5**, 416, 1895.

Orbinsky, A. Nouvelle méthode de détermination des vitesses radiales des étoiles. A. N. **138**, 9–13, 1895.

5. Planets, Satellites and their Spectra.

Barnard, E. E. Micrometrical Measures of the South Polar Caps of Mars. Pop. Ast. **2**, 433–443, June, 1895.

BARNARD, E. E. Micrometrical Measures of the Ball and Ring System of the Planet Saturn, and Measures of the Diameter of his Satellite Titan, Made with the 36-inch Equatorial of the Lick Observatory. M. N. **55**, 367–382, 1895.

BARNARD, E. E. Filar Micrometer Measures of the Diameters of the Four Bright Satellites of Jupiter, Made with the 36-inch Equatorial of the Lick Observatory. M. N. **55**, 382–391, 1895.

BOSSHARD, E. Beobachtungen bei der totalen Mondfinsterniss am 11 März 1895. Sirius **23**, 152–153, 1895.

BRENNER, L. Mars-Beobachtungen an der Manora-Sternwarte nach der Opposition 1894. A. N. **137**, 401–415, 1895.

BRENNER, L. Les taches polaires de Mars, d'après les observations faites a l'Observatoire Manora. Bull. Soc. Astr. France **1**, 184–185, 1895.

BRENNER, L. Ueber die Ellipticität des 1. Jupiter-Mondes. A. N. **138**, 77–79, 1895.

BRENNER, L. Zur Frage über die Venus-Rotation. A. N. **138**, 197–200, 1895.

DESLANDRES, H. Recherches spectrales sur les anneaux de Saturne. C. R. **120**, 1155–1158, 1895.

EDDIE, L. A. The Lunar Eclipse of March 11, 1895. Pop. Ast. **2**, 449–452, June, 1895.

ELGER, T. GWYN. Selenographical Notes. Obs'y **18**, 231–233, 271–274, 1895.

FLAMMARION, C. La circulation de l'eau dans l'atmosphère de Mars. Bull. Soc. Astr. France **1**, 169–176, 1895.

FOULKES, T. H. The Planet Jupiter, as seen on the Evening of 4th March, 1895, at 7:30 P.M. Jour. B. A. A. **5**, 300, 1895.

GEMMILL, S. M. B. The Visibility of the Dark Side of Venus. Jour. B. A. A. **5**, 412, 1895.

GLEDHILL, JOSEPH. Observations of the Phenomena of Jupiter's Satellites and of the Transits of the Red Spot, Dark and Bright Spots, etc., during the Winter of 1894–5. M. N. **55**, 391–398, 1895.

HENDERSON, ARTHUR. An Amateur's Chart of the More Permanent Markings in Jupiter. Jour. B. A. A. **5**, 410, 1895.

HOLMES, EDWIN. On a Probable Cause of Small Spots in Jupiter being Represented Round. Jour. B. A. A. **5**, 409, 1895.

KLEIN. Die Mondbeobachtungen auf der Sternwarte des Harvard College in Cambridge. Sirius **23**, 145–152, 1895.

LYNN, W. T. The Constitution of Saturn's Rings. Obs'y **18**, 235, 1895.

MAUNDER, E. WALTER. Report of the Section for the Observation of Mars. Mem. B. A. A. **2**, Part 6, 157–198.

MEE, ARTHUR. Lunar Enlargements. Jour. B. A. A. **5**, 414, 1895.

MEE, ARTHUR. The Progress of Selenography. Knowl. **18**, 133–135, 1895.

NEWALL, H. F. Micrometer Measurements of Phobos, the Inner Satellite of Mars, during the Opposition of 1894. M. N. **55**, 348–354, 1895.

SEELIGER, H. Bemerkung über die Rotation des Saturnsringes. A. N. **138**, 99–101, 1895.

WILLIAMS, A. STANLEY. On the Rotation of Saturn in 1894. M. N. **55**, 354–367, 1895.

6. COMETS, METEORS AND THEIR SPECTRA.

CORDER, HENRY. Report of the Section for the Observation of Meteors. Mem. B. A. A. **4**, Part 1, 1–20, 1895.

DENNING, W. F. Fireball. Obs'y **18**, 270, 1895.

DENNING, W. F. Meteoric Radiants near γ Pegasi. Obs'y **18**, 233, 1895.

GALE, W. F. The Meteor of Sunday, March 24, 1895. Jour. B. A. A. **5**, 407, 1895.

HUSSEY, W. J. Comet Rordame. Pop. Ast. **2**, 445–449, June, 1895.

MONCK, W. H. S. The Perseid Radiant. Jour. B. A. A. **5**, 363, 1895.

MONCK, W. H. S. Heis's Meteor Radiant T. Obs'y **5**, 274, 1895.

PARKER, DAVID E. Comets and Sun-spot Maxima. Jour. B. A. A. **5**, 362, 1895.

7. NEBULÆ AND THEIR SPECTRA.

MAUNDER, E. WALTER. The Great Nebecula. Knowl. **18**, 156–157, 1895.

ROBERTS, ISAAC. Photograph of the Crab Nebula M. 1. Tauri. M. N. **55**, 399, 1895.

ROBERTS, ISAAC. Photograph of the Nebula near 15 Monocerotis. M. N. **55**, 398, 1895.

8. TERRESTRIAL PHYSICS.

SHELDON, T. S. Auroral Display of March 13. Jour. B. A. A. **5**, 359, 1895.

WEYER, G. D. E. Bestimmung des Convergenzpunktes für die mittleren Richtungen der Magnetischen Meridiane. A. N. **138**, 169–175, 1895.

9. EXPERIMENTAL AND THEORETICAL PHYSICS.

BROCA, A. Sur la courbure de la surface focale des systèmes optiques centrés. Jour. de Phys. **4** (3^{me} sér.), 254–260, 1895.

FITZGERALD, G. F. On Some Considerations Showing that Maxwell's Theorem of the Equal Partition of Energy Among the Degrees of Freedom of Atoms is not Inconsistent with the Various Internal Movements Exhibited by the Spectra of Gases. Proc. R. S. **57**, 312–314, 1895.

FOUSSEREAU, G. Sur l'astigmatisme des lentilles infiniment minces. Jour. de Phys. **4** (3me sér.), 260–262, 1895.

GOUY. Sur une nouvelle méthode pour produire les interférences à grande différence de marche. C. R. **120**, 1039–1041, 1895.

KÖNIG, WALTER. Ueber einige Fälle achromatischer Interferenzen. Wied. Ann. **55**, 1–43, 1895.

LÉPINAY, J. MACÉ DE. Mesures optiques d'étalons d'épaisseur. Ann. Chim. et Phys. **5** (7), 210–255, 1895.

LEWES, VIVIAN B. The Cause of Luminosity in the Flames of Hydrocarbon Gases. Proc. R. S. **57**, 450, 1895.

MERRITT, ERNEST. Ueber den Dichroismus von Kalkspath, Quarz und Turmalin für ultrarothe Strahlen. Wied. Ann. **55**, 49–64, 1895.

SCHUSTER, ARTHUR. Sur les spectres cannelés. C. R. **120**, 987–989 1895.

REIFF, R. Zur Dispersionstheorie. Wied. Ann. **55**, 82–94, 1895.

10. THE SPECTRA OF THE ELEMENTS.

DESLANDRES, H. Comparaison entre les spectres du gaz de la clévéite et de l'atmosphère solaire. C. R. **120**, 1112–1114, 1895.

DESLANDRES, H. Découverte d'une troisème radiation permanente de l'atmosphère solaire dans le gaz de la clévéite. C. R. **120**, 1331, 1895.

DESLANDRES, H. Étude spectrale des charbons du four électrique. C. R. **120**, 1259, 1895.

ETARD, A. Sur l'origine moléculaire des bandes d'absorption des sels de cobalt et de chrome. C. R. **120**, 1057–1060, 1895.

JANSSEN, J. Note sur la loi d'absorption des bandes du spectre de l'oxygène. C. R. **120**, 1306–1310, 1895.

LOCKYER, J. NORMAN. Sur l'analyse spectrale des gaz dégagés par divers minéraux. C. R. **120**, 1103–1105, 1895.

RUNGE, C. Die Wellenlängen der ultravioletten Aluminiumlinien. Wied. Ann. **55**, 44–48, 1895.

RUNGE, C. On the Line Spectra of the Elements. Nat. **52**, 106–108, 1895.

RUNGE, C. Terrestrial Helium (?) Nat. **52**, 128, 1895.

RAMSAY, W. and J. NORMAN LOCKYER. Terrestrial Helium. Nat. **52**, 55–57, 1895.

11. PHOTOGRAPHY.

WIENER, OTTO. Farbenphotographie durch Körperfarben und mechanische Farbenanpassung in der Natur. Wied. Ann. **55**, 225–281, 1895.

12. INSTRUMENTS AND APPARATUS.

BROOKES, WM. R. On a Modified Form of the Cassegrain Telescope. M. N. **55**, 324, 1895.

COMMON, A. A. The Brachy Telescope of Messrs. Fritsch & Forster, of Vienna. M. N. **55**, 325, 1895.

DAVIES, C. D. P. Note on a Suggested Form of Equatorial Mounting for a (Modified) Newtonian Reflector. M. N. **55**, 400–404, 1895.

DENNING, W. F. The Relative Powers of Large and Small Telescopes in Showing Planetary Detail. Nat. **52**, 232–234, 1895.

HALLWACHS, WILHELM. Bemerkung zu einer Arbeit des Hrn. Borgesius über ein Interferenzrefractometer, etc. Wied. Ann. **55**, 282–287, 1895.

LAGRANGE, CH. Observations comparées de declinometres à moments magnétiques différents. C. R. **120**, 1333, 1895.

LIPPMANN, G. Sur un coelostat, ou appareil à miroir, donnant une image du Ciel immobile par rapport à la Terre. C. R. **120**, 1015–1019, 1895.

PRINZ, W. Les grands instruments astronomiques et leur rendement photographique. Ciel et Terre, **6**, 121–130, 153–163, 1895.

STREHL, KARL. Die Berechnung der Fernrohrobjektive im Lichte der Beugungstheorie. Sirius, **23**, 159–163, 1895.

TURNER, H. H. On a Simple Apparatus for Measuring Stellar Photographs. Jour. B. A. A. **5**, 400, 1895.

WOLF, MAX. Die Regulirung des Uhrwerkes eines photographischen Fernrohrs. Z. f. Instrum. **14**, 203–214, 1895.

13. GENERAL ARTICLES, MEMOIRS AND SERIAL PUBLICATIONS.

BACKHOUSE, T. W. Is the Zodiacal Light Variable. Jour. B. A. A. **5**, 307, 1895.

BERTHELOT. Nouvelle combinaison de l'argon; synthèse et analyse. C. R. **120**, 1316–1320, 1895.

BERTHELOT. Nouvelles études sur la fluorescence de l'argon et sur sa combinaison avec les éleménts de la benzine. C. R. **120**, 1386–1390, 1895.

CLÈVE. Sur la densité de l'helium. C. R. **120**, 1212, 1895; Chem News **71**, 283, 1895.

CORDER, HENRY. The Zodiacal Light. Jour. B. A. A. **5**, 305, 1895.

GEMMILL, S. M. B. The Zodiacal Light. Jour. B. A. A. **5**, 306, 360, 1895.

GOULD, B. A. Memoir of Lewis Morris Rutherfurd, 1816–1892. Nat. Acad. Sciences, April, 1895.

JANSSEN, J. Sur l'observatoire d'Astronomie physique de Meudon. C. R. **120**, 1237–1240, 1895.

MARKWICK, E. E. Observations of the Zodiacal Light. Jour. B. A. A. **5**, 419, 1895.

MCLEOD, HERBERT. The Bibliography of Spectroscopy. Nat. **52**, 105, 1895.

RAMSAY, W. Argon and Helium in Meteoric Iron. Nat. **52**, 224–225, 1895.

RAMSAY, W. Sur l'argon et l'hélium. C. R. **120**, 1049, 1895.

RAYLEIGH, LORD. Argon. Nat. **52**, 159–164.

SCHEINER, J. Untersuchung über die Spectra der Helleren Sterne nach Photographischen Aufnahmen. Pub. Astr. Obs. Potsdam **7**, Part II, 171–335, 1895.

SPÖRER, G. Beobachtungen von Sonnenflecken in den Jahren 1885 bis 1893. Pub. Astr. Obs. Potsdam **10**, 1–149, 1895.

TISSERAND, F. Bulletin du Comité International Permanent pour l'exécution photographique de la Carte du Ciel. **2**, 347–458, 1895.

——— Report of the Incorporated Kew Committee for the Year Ending December 31, 1894. Proc. R. S. **57**, 500–530, 1895.

——— Report of Magnetical Observations at Falmouth Observatory for the year 1894. Proc. R. S. **57**, 530, 1895.

NOTICE.

The scope of THE ASTROPHYSICAL JOURNAL includes all investigations of radiant energy, whether conducted in the observatory or in the laboratory. The subjects to which special attention will be given are photographic and visual observations of the heavenly bodies (other than those pertaining to "astronomy and position"); spectroscopic, photometric, bolometric and radiometric work of all kinds; descriptions of instruments and apparatus used in such investigations; and theoretical papers bearing on any of these subjects.

In the department of *Minor Contributions and Notes* subjects may be discussed which belong to other closely related fields of investigation.

It is intended to publish in each number a bibliography of astrophysics in which will be found the titles of recently published astrophysical and spectroscopic papers. In order that this list may be as complete as possible and that current work in astrophysics may receive appropriate notice in other departments of the JOURNAL, authors are requested to send copies of all papers on these and closely allied subjects to both Editors.

Articles written in any language will be accepted for publication, but unless a wish to the contrary is expressed by the author, they will be translated into English. If a request is sent *with the manuscript* twenty-five reprint copies of each paper, bound in covers, will be furnished free of charge to the author. Additional copies may be obtained at cost price. No reprints can be sent unless a request for them is received before the JOURNAL goes to press.

The Editors do not hold themselves responsible for opinions expressed by contributors.

THE ASTROPHYSICAL JOURNAL will be published on the first day of every month except July and September. The annual subscription price for the United States, Canada and Mexico is $4.00; for other countries in the Postal Union it is 18 shillings. Correspondence relating to subscriptions and advertisements should be addressed to *The University of Chicago, University Press Division, Chicago, Ill.*

Wm. Wesley & Son, 28 Essex St., Strand, London, are sole foreign agents, and to them all European subscriptions should be addressed.

All papers for publication and correspondence relating to contributions and exchanges should be addressed to *George E. Hale, Kenwood Observatory, Chicago, Ill.*

Volume II, Number 5

The Physical Review

A Journal of Experimental and Theoretical Physics

CONDUCTED BY

EDWARD L. NICHOLS AND ERNEST MERRITT

XI.

March—April, 1895

TABLE OF CONTENTS

On the Attractions of Crystalline and Isotropic Masses at Small Distances A. STANLEY MACKENZIE 321

The Influence of Temperature upon the Transparency of Solutions EDWARD L. NICHOLS and MARY C. SPENCER 344

Determination of the Electric Conductivity of Certain Salt Solutions ALBERT C. MACGREGORY 361

The Apparent Forces between Fine Solid Particles Totally Immersed in Liquids. II. W. J. A. BLISS 373

Minor Contributions: (1) Surface Tension of Water at Temperature below Zero Degree Centigrade; *W. J. Humphreys* and *J. F. Mohler*. (2) Variation of Internal Resistance of a Voltaic Cell with Current; *H. S. Carhart* 387

New Books: *Ostwald:* Manual of Physico-Chemical Measurements; translated by J. WALKER. *Lodge:* The Work of Hertz and Some of his Successors. *Ziwet:* An Elementary Treatise on Theoretical Mechanics. *Miethe:* Photographische Optik ohne mathematische Entwickelungen für Fachleute und Liebhaber. Proceedings of the International Electric Congress. The American Annual of Photography and Photographic Almanac 395

COPYRIGHT, 1895, by MACMILLAN & CO.

Published for Cornell University

Macmillan & Company

New York London

BERLIN: Mayer & Mueller

JOHN BYRNE'S

Astronomical and Terrestrial

TELESCOPES

Of three, four, five, six inches and larger apertures

Short Focus and Brilliant Light

Inimitable for Perfection of Figure, Sharpness of Definition, and Accuracy of Color Correction. Send for Catalogue to

GALL & LEMBKE

Opticians

21 Union Square, New York City

LOUIS MÜLLER-UNKEL, Braunschweig, Germany

(Partners: L. Müller-Unkel and R. Müller-Uri)

MANUFACTURERS OF

Blown Glass for Scientific Purposes

All kinds of Lecture Apparatus and Supplies.
Lecher's Tubes for Hertz's Experiments.
Lenard's Tube for Kathode Rays.
Thomson's Globes.
Plücker's Spectrum Tubes and Geissler Tubes.

SOLE MAKERS OF . . .

Elster and Geitel's Photo-electric Apparatus

Reflecting Telescopes

CALVER'S COMPLETE and UNIVERSAL EQUATORIAL (Patent)

comprising many great improvements; adjustable to any latitude; truly revolving eye-end, etc. Clock can drive Telescope with or without clamping. Second-hand **12½-in. Equatorial Reflector,** complete without Clock; **8½-in. Alt-Azimuth,** own make, guaranteed; also, **4¼-in. Equatorial Refractor,** also first quality. Full particulars, with illustrated catalogue, of all styles.

G. CALVER, F.R.A.S., Chelmsford, England.

The E. Howard

Watch and Clock Company

383 Washington Street, Boston 41 Maiden Lane, New York

34 Washington Street, Chicago

MANUFACTURERS OF

Astronomical Regulators

Regulators of Precision and Fine Watches

To any of our Regulators

We attach devices for the transmission of electrical currents for operating chronographs, sounders (indicating the time of the standard regulator), or for synchronizing secondary clocks when desired.

These Electrical Transmitting Devices

Can be attached to our No. 89 Regulator, which is especially constructed to meet the wants of the railroad service; and the almost absolute certainty and regularity of the performance of these Regulators make them particularly desirable as secondary standards for the railroad service.

To our Astronomical Regulators

We apply either Dennison's Gravity or the Graham Dead-Beat escapement. These Regulators are made in several grades, thereby meeting the wants of institutions having ample means for the purchase of the most elaborate form of time-keeping instruments, as well as newly established institutions with limited means to invest in a regulator.

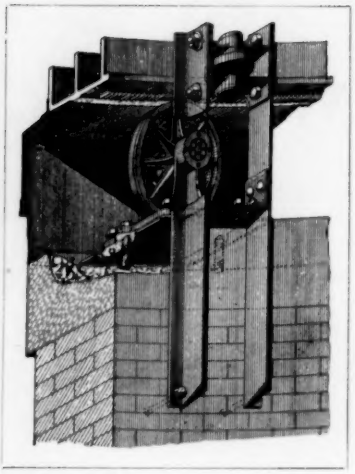
Our Watches

Are second to none in the world as time-keepers, and the manner of their construction is such that they are less liable to injury from improper handling than any other watch now in the market.

We Respectfully Solicit Correspondence

From corporations, institutions, and individuals contemplating the purchase of a Regulator, regardless of the grade.

Domes



For Astronomical Observatories built on the Hough System possess the following advantages over all others:

Minimum weight of rotating parts.

Perfect alignment, by the use of adjustable, stationary, roller-bearing wheels; consequent ease of rotation, and lateral stability under all conditions.

An opening continuous from horizon to zenith.

A shutter that closes weather tight, will not bind, and can be quickly and easily operated.

Simplicity of construction, durability and cheapness.

The roller-bearing wheels and the shutter can be applied to existing domes, with slight alterations and at moderate expense.

Domes Built on the New Method

may be seen at the Dearborn Observatory, Northwestern University, Evanston, Illinois; at the Observatory at Denver, Colorado, and at Cincinnati, Ohio.

For further particulars and estimates of cost, address,

C. L. STROBEL, C. E.

1744 Monadnock Block, Chicago, Ill.

BOOKS AND PAMPHLETS

OF

THE UNIVERSITY OF CHICAGO PRESS

SYNTAX OF THE MOODS AND TENSES IN NEW TESTAMENT GREEK. By Ernest D. Burton, Head Professor of New Testament Literature and Exegesis in The University of Chicago. Second Edition, revised and enlarged. Cloth, large 12mo, 22+215 pages. Price, $1.50 *net*.

ASSYRIAN AND BABYLONIAN LETTERS BELONGING TO THE K COLLECTION OF THE BRITISH MUSEUM. By Robert Francis Harper, Ph.D., of The University of Chicago. Vol. I., cloth, 8vo, 15+116 pages of texts, 124 texts in all. Price, $7.00. Vol. II., cloth, 8vo, 112 pages, 100 texts in all. Price, $7.00.

ECONOMIC STUDIES OF THE UNIVERSITY OF CHICAGO

I. THE SCIENCE OF FINANCE; an authorized translation of Gustav Cohn's *Finanzwissenschaft*, by Dr. T. B. Veblen, of The University of Chicago. NOW READY. Large 8vo, cloth, 12+800 pages. Price, $3.50 *net*.

II. HISTORY OF THE UNION PACIFIC RAILWAY. By Henry Kirke White. *Ready about June 25*. Large 8vo, cloth, about 150 pages.

III. THE INDIAN SILVER CURRENCY. By Karl Ellstaetter. Translated from the German by Professor J. Laurence Laughlin. *In Press*.

IV. HISTORY OF THE LATIN UNION. By Henry Parker Willis. *In Preparation*.

STUDIES IN CLASSICAL PHILOLOGY

I. VITRUVIUS AND THE GREEK STAGE. By Edward Capps. 8vo, paper, 24 pages. Price, 25 cents.

II. THE ANTICIPATORY SUBJUNCTIVE IN GREEK AND LATIN. By William Gardner Hale. 8vo, paper, 92 pages. Price, 50 cents.

III. THE OSCAN-UMBRIAN VERB SYSTEM. By Carl Darling Buck. 8vo, paper, 68 pages. Price, 50 cents.

GERMANIC STUDIES

I. DER CONJUNKTIV BEI HARTMANN VON AUE. By Starr Willard Cutting. 8vo, paper, 54 pages, with 24 inserts of charts and tables. Price, 50 cents.

FOOD AS A FACTOR IN STUDENT LIFE. By Ellen H. Richards and Marion Talbot. 8vo, paper, 28 pages. Price, 25 cents.

HISTORY OF THE ENGLISH PARAGRAPH. By Edwin Herbert Lewis. 8vo, paper, 200 pages. Price, 50 cents.

THE CONSTITUTION OF THE ARGENTINE REPUBLIC AND THE CONSTITUTION OF THE UNITED STATES OF BRAZIL. By Elizabeth Wallace. 8vo, paper, 96 pages. Price, 50 cents.

NOTES ON MEXICAN ARCHÆOLOGY. By Frederick Starr. 8vo, paper, 16 pages, with plates. Price, 25 cents.

PHALLICISM IN JAPAN. By Edmund Buckley. 8vo, paper, 36 pages, with frontispiece. Price, 50 cents.

Any of the above publications will be sent, postage prepaid, on receipt of price.

All remittances, for books or subscriptions, should be made payable to the order of THE UNIVERSITY OF CHICAGO.

All orders, or subscriptions, should be sent to

THE UNIVERSITY OF CHICAGO,

THE UNIVERSITY PRESS DIVISION, CHICAGO, ILL.

POOLE BROTHERS' CELESTIAL PLANISPHERE

A CHART OF THE HEAVENS.

Designed to show the Student the places of the Constellations at any given moment.

For the use of Observers, the Publishers have for sale SPECIAL SHEETS of the PLANISPHERE printed on a suitable paper, so that the Student may make and keep a Record of any Celestial Phenomena of Special Interest, such as the Paths of Planets, Comets, Shooting Stars, etc. **Prepaid to any Address** { **Single Sheets. 25 cents.** **Per Dozen, $2.00.**

POOLE BROTHERS' CELESTIAL HANDBOOK

CONCISE AND ACCURATE.

Companion to the Celestial Planisphere and Explanatory of its uses, besides other desirable Astronomical Information for both the Amateur and the Advanced Student.

It is difficult to imagine how astronomy could be studied under more favorable auspices than with this Planisphere and the very elegantly illustrated descriptive Handbook accompanying it.—Scientific American, Feb. 18th, 1893.

THE MOON

A NEW AND COMPLETE MAP OF OUR SATELLITE.

Compiled by Jules A. Colas, from the Map of C. M. Gaudibert, drawn by L. Fenet, under the direction of C. Flammarion; size 24½ x 29 inches; diameter of Lunar disc 20¼ inches. Printed with blue background, representing the color of the sky in full moonlight. the disc being colored to represent well the seas, plateaus, mountains, craters and streaks as they appear in the telescope.

Accompanying the map is a full Index Pamphlet of twenty-four pages, with notes by Prof. W. W. Payne.

For Descriptive Circulars and other information, address

POOLE BROTHERS,
316 Dearborn Street, CHICAGO, ILL.

WILLIAM WESLEY & SON,
AGENTS,
28 Essex Street, Strand, London, Eng.

ALVAN CLARK & SONS

CAMBRIDGEPORT, MASS.

Manufacturers of

ASTRONOMICAL TELESCOPES

With Improved Equatorial Mountings

Sizes from Four-inch Aperture
to the Largest Ever Ordered

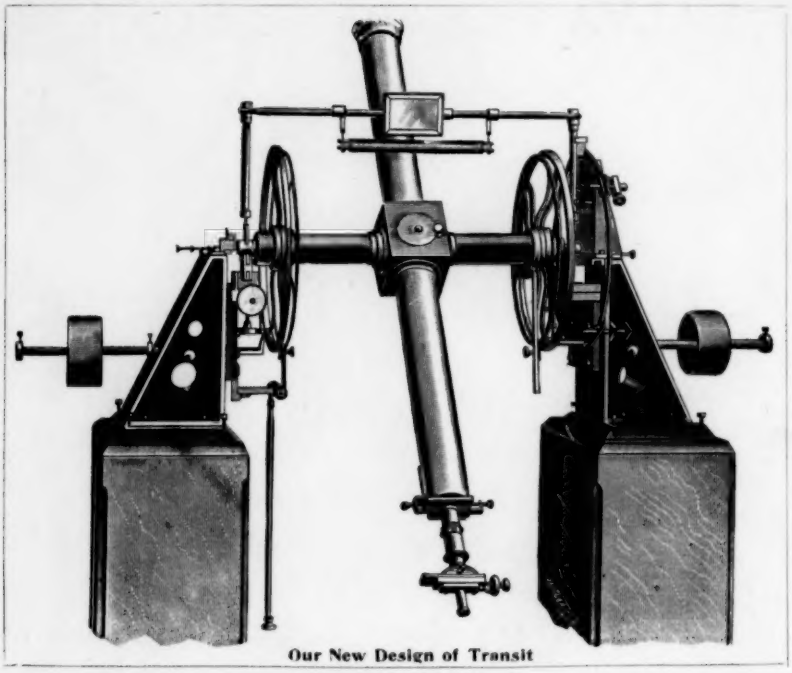
Send for Photographs of our Portable Equatorials or five and six-inch fixed, with accessories — the best to be had for educational and amateur work.

Terrestrial Telescopes for private residences.

The performance of our instruments, famous the world over, is their own greatest recommendation. An experience of nearly a half century in the art of telescope making enables us to apply a degree of skill and judgment to our work which make our objectives **unrivalled in excellence.**

Among our telescopes are

The Lick Refractor, 36-inch.
Pulkowa Refractor, 30-inch.
Washington Refractor, 26-inch.
University of Virginia, 26-inch.
Princeton Refractor, 23-inch.
Denver Refractor, 20-inch.
Chicago Refractor, 18.5-inch.
Rochester Refractor, 16-inch.



Our New Design of Transit

Parties seeking anything in this line will find it advantageous to address

CENTRAL SCHOOL OF MECHANICAL ENGINEERING

Davenport, Iowa

C. A. STEINHEIL SÖHNE

Optical and Astronomical Works

Munich, Bavaria

Established 1855

Manufacturers of instruments for Astronomical and Physical Research, Telescopic Objectives of all sizes, Oculars, Magnifiers (aplanatic), Prisms, Telescopes for Visual and Photographic Purposes, Parallel Plates, Spectroscopic Apparatus (the first instruments used by Kirchhoff and Bunsen were made here).

Catalogues (in English) may be had post-paid on application